PHD

'Mapping surgeons' mapping the body': Graphic renderings of visualisation, representation and dimensionality in (veterinary) surgical practice

Woodgate, Dawn Alison

Award date:
2001

Awarding institution:
University of Bath

'Mapping surgeons' mapping the body': Graphic renderings of visualisation, representation and dimensionality in (veterinary) surgical practice.

submitted by Dawn Alison Woodgate
for the degree of PhD, 2001
University of Bath

Dawn Woodgate.

CONTENTS

ABSTRACT

I present an ethnographic account of surgical operations, via which I have investigated two principal issues. Firstly, people's uses of representations (verbal, visual, two-dimensional, three-dimensional), in performing complex tasks, and solving complex problems, and secondly, the ways in which these uses change as they gain in experience. Using a reflexive, interdisciplinary approach, I have shown strategies by which actual bodies become 'merged' with anatomical pictures and other representations of them (Hirschauer 1991), enabling surgeons to map the internal body during operations.

Initial evidence from sculptors showed that 2D pictures are frequently used as sources of ideas, for problem solving, or as rhetorical devices in the making of 3D art. Their use as 'blueprints' or plans, or as models to copy directly, is however problematic. *Numbers* of pictures were preferred to individual ones, and these tended to be combined and superimposed together in various ways. These uses of pictures were also shown in observations of surgeons.

I have identified 'primary enhancement' and 'reduction' procedures (ie, the pre-operative preparations that surgical patients undergo), and 'further enhancement' procedures (which may include physical interventions, the use of anatomical pictures and other images, and language - literally verbal 'bodymapping'), which allow the body to be mapped, and become known. Thus the body is subjected to alternating processes of enhancement and reduction which make successful surgical intervention possible.

These procedures may be differentially applied by *individual* surgeons with differing amounts of experience of a particular operation Further enhancement procedures may also be differentially used by *groups* of surgeons performing 'actual' and 'virtual' operations; that is, involved in the practical performance of a surgical procedure, or alternatively in the active observation of it, peripheral to it, but still very much involved. Surgeons thus become skilled 'operators' via the performance of actual and virtual operations

ACKNOWLEDGEMENTS

I would like to express especial thanks to my supervisors, Professors Helen Haste and David Gooding for their help and support over the duration of this research. I would particularly like to thank David for his invaluable comments on my first draft, and Helen for her seemingly unshakeable assumption that I could in fact *do* this, even when I was not at all sure that I could. Having said this, any mistakes or omissions are entirely my own!

I would also like to thank the rest of the academic and other staff, and fellow postgrads in the Department of Psychology and elsewhere for their company and support. A special mention for the administrative staff, for letting me work with them and helping keep me sane during the past year. The library staff too, have been extremely helpful in tracking down for me sometimes obscure references and inter-library loans.

My research respondents deserve particular thanks, for allowing me to observe and interview them. Without them, there would have been no research! I cannot thank them personally here, since I promised anonymity, but many thanks to all of you, both those who feature directly in the following pages and those who do not. My admiration for your skill and humanity knows no bounds!

My grateful thanks to all my students past and present, in all of their different locations, for all that they have taught me. Lastly, I would like to thank my family and friends away from the University for all their support.

DEDICATION

For my father and my sister.

William Maurice Kasvin Taylor
1 January 1927 - 14 January 1991.

Karen Jane Taylor
29 January 1961 - 23 December 1984

LIST OF FIGURES

CHAPTER 1: BEGINNINGS...

'I dislike introductions; what they convey, when not superfluous, is usually premature...'
Jerry Fodor (1981)

1.1 Introduction (nevertheless)

What follows is above all about knowing, seeing, and how we come to know and see. It is intended as a contribution to the study of work and of skill, and stems from a long-term interest in the 'thinking and doing' processes of people who do skilled work with their hands and heads. Using examples (mainly) from veterinary surgery, my principal aim is to examine both the ways in which we accrue and apply knowledge, and to consider also the role of 'mental' and 'physical' visual imagery in skilled task performance. I adopt the terms 'mental' and 'physical' in an attempt to differentiate between our internal, mental images, and their physical counterparts such as diagrams, photographs or the images that result from the application of technologies such as radiology. I am aware that this mental / physical dichotomy is in itself problematic; it may be for example that we do not in fact discriminate between them when we come to actually *use* imagery, to nearly the extent that we do when we *discuss* it.

I apply these terms here in preference however to those related ones of 'abstract' and 'concrete'. This terminology is particularly problematic since *all* images could be thought about as abstractions from things in the world. Arnheim (1969) described the unitary nature of perceiving and thinking, stressing that at every level, this *single* cognitive process involves abstraction. Whilst I endorse this view, I nevertheless make use of related terms here, (unwillingly, and in the absence of any better), in an attempt to communicate what I wish to do. Difficulty in 'finding the right words' to express complex ideas and processes forms an important theme running throughout this thesis; one that will be revisited again and again.

My research represents not only an attempt to investigate the ways in which skilled practitioners tackle the complex tasks that form part of their work routines, but an attempt also (on my own part) to *render more visible* this complexity. Some aspects of the ways in which people approach and perform such tasks have a tendency to become hidden by the very mechanisms by which they are described and communicated, and as a result remain essentially unacknowledged. This work represents an attempt to make more explicit some of these tacit processes, and provide some insights into the ways in which practitioners represent a domain in which they are trying to solve problems, using the example of one particular domain; that of the body.

Research of this type is usually considered to be purely cognitive in nature, and therefore confined within the boundaries of psychology. Numerous other studies concerned with visual cognition and problem solving have made use of psychological experiments, (eg, Pylyshyn 1973; Kosslyn 1980; Kosslyn, Brunn, Cave & Wallach 1984). More recently, research on mental imagery in particular has become increasingly 'neuropsychological'; related to findings about brain structure and function, (eg, Tippett 1992; Kosslyn 1994). I have chosen however (after much thought and research) to avoid these routes, and instead to do ethnographic work in natural settings, and construct case studies of actual procedures based upon this fieldwork. In doing so, I hope that this work, rather than purely 'psychological' in nature, will be considered to be of broader disciplinary relevance. Thagard (1999) identified 'social' and 'physical' aspects or dimensions that exist, (alongside the 'cognitive' one) in his study of explanations in science. *Explaining*, like *bodymapping* is also an activity that could be entirely relegated to psychology. Like Thagard however, I attempt to demonstrate how fuller explication can result from a more wide ranging and inclusive approach.

Also, without wishing to discount the considerable importance of experimental psychology to this topic, (and indeed, I refer to such studies at various points within my text), I feel, following Wundt (1916), Bartlett (1958), Neisser (1976), Cole *et al* (1978), Lave (1997) and Scribner (1997), that everyday problem solving situations are very different from laboratory ones in a number of important ways. For example, although any work situation is much more complex than a laboratory experiment, certain types of problems tend to occur over and over again within them, (even if they are not *exactly* the same each time), rather than the problem being totally decontextualised from normal everyday working life and experience. Also, unlike psychology laboratories, work situations tend to be rich sources of the sorts of tools and information needed for solving work-specific types of problems. Finally, the problems that need to be solved in the course of skilled practice are usually a means to an end, rather than an end in themselves, as laboratory based problems tend to be.

These differences have been particularly well documented by Lave (1997) who studied how unschooled tribal craftsmen solved arithmetical problems both within their familiar work context, and also in the laboratory. Scribner (1997) studied US factory workers solving similar types of problems, again both inside and outside of the work context, and found similar results. Both researchers found that their subjects, although skilled at solving almost identical problems as part of their work, found it very difficult to do so when the problems were decontextualised as psychology laboratory experiments.

1.2 Of surgical practices....

'But this morning, as the surgeon parts the edge of the wound with his retractor, he feels uncertain, for in that place where he ***knows*** *the duct to be, there is none...'*
Robert Selzer 1981

Veterinary surgery is fascinating, and under-researched even in comparison with a 'human' counterpart that is itself not extensively researched. Pinch, Collins and Carbone (1996) used it as a context to examine some of the ways in which task uncertainty may be resolved in practice, and this interesting study represents in some ways a starting point for my own. They described this work as a 'second order study of skill' which, whist accepting that skills and their transmission are the properties of social groups, wished to examine in detail which aspects of skills can be explicated and which cannot. They identified a 'quasi-quantitative measure of skill acquisition - hardness' (ibid p.163)[1], which may have value in contributing to a wider understanding of how task uncertainty is resolved in practice and how new skills are learned.

Another influential study is that of Hirschauer (1991), who showed how the bodies of (human) surgical patients are 'made operable', and 'anatomical visibility' created by means of 'highly skilled manipulations and optical technology'. Both Pinch and his co-workers and also Hirschauer have used an ethnographic approach similar to my own. Like Pinch, Collins and Carbone, I am interested in skills and their transmission within a culture, and in the same sort of way as Hirschauer, I wish to examine the ways in which the 'language' of anatomy may be 'read' by practitioners who possess the appropriate skills. Both of these studies were concerned to some or other extent with surgeons' 'bodymapping' activities during operations. One of my intentions here is to carry this theme further by shedding some light upon the actual variations that occur in some of these processes when the 'same' operation is carried out by surgeons with differing amounts of practical experience.

Surgical operations, as well as being very interesting, have certain other advantages as a research topic over, for example, the *sculptural* procedures discussed in chapter 7. There, I report findings from a pilot study relating to art and craft practices which I have loosely termed 'sculpture'. A surgical operation (unlike the processes involved in making a sculpture) necessarily takes place within a relatively short timespan (though obviously the precise duration varies according to the actual procedure, as well as other factors which will be discussed below). It also has a clearly defined beginning, middle and end. It is useful to think about a surgical procedure (any surgical procedure), as consisting of four stages. Stage 1 involves the pre-operative preparation, including the induction of anaesthesia, stage 2 the incision, stage 3 is the actual procedure itself; this may consist for example of the excision of unwanted material, or the repair of broken bones. The fourth stage is the closure of the incision. These stages will be further discussed, and illustrated further on, particularly in chapters 8 and 9.

The (1996) study carried out by Pinch, Collins and Carbone, whilst emphasising the social dimension ubiquitious in some areas of science studies, acknowledges also the importance of a cognitive one which exists alongside it. Thagard's (1999) inclusion of a physical dimension in addition to these social and cognitive ones is also noteworthy because of this dimension's particular emphasis in more recent debates within the philosophy of science. For Thagard, this physical dimension includes within it such things as scientists' uses of experimentation, and also the tools, equipment and external representations (such as books and diagrams) that they use. Gooding (1996a) in his consideration of experimentation, included thought experiments alongside actual, physical ones, thereby drawing a further link between the physical and the cognitive.

Thought experiments, like mental representations, are undeniably 'cognitive' things, and 'real' experiments physical in nature. However, in the same sort of way as with mental representations and their physical counterparts, the ways in which we use them at times render it difficult to distinguish between them. Pinch, Collins and Carbone (1996) then, stressed cognitive aspects which exist alongside the social ones within their chosen context, and Gooding, (1996a) the physical alongside the cognitive ones within his. Thagard however has taken this further, choosing to give more or less equal weight to all three of these 'dimensions'. I shall attempt to do the same.

Katz (1981) and Hirschauer (1991) emphasised the importance of the sterility procedures which surround surgical operations (carried out upon human patients). Rather than being seen merely as infection prevention measures, these are better understood as ritual practices designed to deal with the taboos which surround the human body, (which is not an issue here), or to increase efficiency by allowing autonomy of action, thus enabling workers to function in situations of ambiguity. This last point is relevant, and interesting, since these procedures are important within veterinary surgery also, and not merely from the obvious standpoint of asepsis.

1.3 Mapping surgeons' mapping of the body ...

Of major concern to all surgeons is the body; its cartographies, both internal and external, its functions and form, the ways in which we apply our knowledge about it, and how it is represented. As a practice, surgery has its own special knowledge (quite apart from more 'general' knowledge that we all share) about the body. Recent work suggesting the importance of visual imagery (both the internal, mental kind and also external, physical representations), to the *natural* sciences, has prompted me to consider its use in the context of my own work, concerned as it is with the *applied* scientific discipline of surgery. I refer specifically to the ways in which surgeons map the body during operations. Not only from the point of view of my research subjects' own use of such devices (although this is obviously of great relevance), but also ways in which I might myself use them to help explicate a complex, dynamic process that seems difficult to express adequately in words alone. As the art historian Barbara Stafford (1991 p.2) has stated, some things (even quite fundamental ones) are, and remain very hard to express verbally.

Some examples of what she terms these inarticulable relationships are those important ones (to me) of interior / exterior, and idea and form.

I will argue that, when preparing to perform operations, surgeons need in some way to 'map' or visualize the internal body. Since it is to be expected that individual variations exist in the interior (as well as the exterior) appearance of bodies, it cannot be assumed, even if a surgeon has carried out a particular procedure on one or more previous occasions (or watched someone else doing it, or looked at pictures in a textbook), that the organs in *this* case will be exactly the same in appearance (and even their position may vary to some extent), or for that matter that the procedure's trajectory will be exactly similar *this* time. The quote from Selzer at the head of the previous section is illustrative of this. Hirschauer (1991, p.310) explicitly described a need for specialism in surgery; he asserted that the visual complexity of the body forces every student surgeon into the disciplinary differentiation of the field.

Veterinary surgeons are therefore particularly interesting to study in this respect because, not only do they not specialise in the same way as surgeons in 'human' medicine (even 'specialists' do more 'general' work as well, in most circumstances), *but they may work also with the full range of animal species*. In addition to having to contend with the whole of anatomy in a way not encountered by their 'human' counterparts, encompassing *individual* anatomical differences that may occur in any part of the body, vets have also to contend with *species* differences, and for that matter, even differences between the different *classes* of animals, such as mammals, birds and reptiles.

It must be borne in mind that at the outset, before any incision is made, the body's (any body's) bones and internal organs are in most cases *invisible*. An operation may be carried out with or without the aid of pictures in textbooks, or those produced by means of technological interventions such as radiography. Such devices could be said to *expand* the senses, providing if you like extra sensory perceptions, which allow the *interior* of the body to be viewed or visualized from the *exterior*. In addition to these sensory *expansion* devices, certain *reduction* processes may also be of importance to the visualisation process. For example the anaesthetised animal is carefully positioned. It may be placed in a device to hold it steady in the desired position, and /or one or more of its limbs tied to the legs of the operating table to hold them out of the way. The entire body will usually be covered with drapes, with the exception of the immediate area where the incision is to be made. Additionally, in animal patients the incision site is shaved, which has the effect of further *demarcating* it from the remainder of the body. The site may be further *marked* by painting it with antiseptic, or even drawing the line of the intended incision.

After the initial incision has been made, the internal body must be (re)constructed in the sense of identifying individual organs and their relations to each other. This (re)construction process may be made more difficult by the obscuring presence of blood, muscle, fat, mesentery and other bodily substances, and the facts that both individual variations exist in the relative size, position and so forth of even normal organs (diseased organs and broken bones may obviously vary even more in appearance); also, that the body is made up of a number of layers, the organs overlying each other. Xray images, or pictures in anatomical atlases or surgical manuals may be consulted again at this point. However, it is important to recognise that the content of some of these representations is itself problematic; a measure of expert interpretation is required in order that they be of any use at all.

The question of dimensionality too, is an interesting one. Most pictures are two dimensional, and practical 'reality' usually occurs in three dimensions. I discount here the use of such medical imaging technologies as magnetic resonance imaging (MRI) and computer aided tomography (CT), which do give images more approaching three dimensions, simply for the reason that these are not used in general veterinary practice at the time of writing, (and are therefore unavailable to me as data sources in this investigation). Beaulieu (2000) however has studied these developing practices in real time, and this research adds interesting insights to previous studies of developing optical or visualization technologies, the interpretation of images produced by them, and their integration into mainstream discourses.

My own respondents needed in some way to accommodate a switch between dimensions that occurs when they use pictures to aid with the visualisation of three dimensional tasks. Gooding (1996a p.94) described a process in the early stages of scientific innovation, which he termed 'dimensional reduction and enhancement', in which dimensions are first subtracted, then added to existing images (which may be either mental images or tangible images in the real world, such as pictures) to create new images to aid inference. I will later argue that a variation of this posited process could be put forward as an explanation for the method by which surgeons map the body in complex operations.

1.4 ... And 'sculptural' practices...

Hirschauer (1991) described surgery as a 'sculptural practice' which relates 'experience and representation' in explaining how patients' bodies come to 'embody the properties of anatomical pictures'. Surgery, like sculpture, he argued, is 'a sequence of looking and cutting' (p.299). The use of this intriguing metaphor has prompted me to consider also the 'practice' of sculpture itself. How is it similar for example, and how does it appear to differ from surgery? If surgery can be described thus as a 'sculptural practice', then perhaps the practice of sculpture (or at least, sculptors) can help shed some additional light upon the research questions, particularly since veterinary surgeons, like Hirschauer's subjects, are often very bad informants during operations.

The two practices seem, at least on the surface, to be very different in nature. Surgery can be termed broadly 'scientific', or at least 'applied-scientific', (Hirschauer (1996 p 279 / 314) referred to it as an 'applied science'); sculpture belongs unquestionably to the realm of 'the arts'. I have chosen these examples advisedly; partly pragmatically (ie, access was possible, although as I will relate later, not always easy), but also *because* of these perceived differences. Our society tends rightly or wrongly to segregate rather strictly 'artistic' from 'scientific' pursuits, assigning to them not only different modes of education and areas of concern, but in some senses differential status also. Historically this has not always been the case. It *is* the case though, somewhat paradoxically, that, although it seems to be accepted that science and art are 'different' from one another in various ways, precisely what these differences *are* is hard to pin down. Also, their actual *content* is frequently subject to debate; for example, what exactly constitutes a valid work of art? Painting and sculpture (or at least, *realist* paintings and sculptures) are rarely criticised as not being 'real' art, most especially when they are produced by 'real' artists. But how about more abstract pieces, particularly those in which use is made of non-traditional media or materials? Science too, is subject to its own questions and debates. What characterises 'hard' science? Can biology and psychology for example be termed 'real' sciences in the same sense as physics or mathematics? And how about the 'quasi-sciences' of the paranormal? This thesis bears upon, and contributes to debates about these important issues.

Quite apart from this conventional art / science dichotomy (whose apparent denial, or refutation will inevitably characterise my work as 'interdisciplinary' - or 'undisciplined' perhaps?), there exist others. Neither is it merely the empirical subject matter that spans disciplinary areas. My literary sources also originate from a range of disciplines; art and art history, history of science, sociology, psychology, artificial intelligence and others are represented in my bibliography, and despite the fact that I carry out real-time research, the conferences to which I have been invited to contribute, have been history ones.

Another of the ways in which my chosen practices could be categorised is that of their attributed relative status. Veterinary medicine is unquestionably a 'profession' in a society in which professional occupations are rather highly valued and rewarded. The position of sculpture is rather more ambiguous. Could sculpture be termed a 'profession' and sculptors 'professionals' in the same sort of way as veterinary surgeons? The term 'profession' itself, and exactly what contributes to a particular occupational group being considered 'professionals' are subject to debate. Also, the process of 'professionalisation' (that is, the process by which an occupational group gains professional status), is a focus for discussion. Eraut (1994 p.1) described the boundaries of 'professionalism' as ill defined, and discussed the many attempts that have been made to provide an adequate definition. Etzioni (1969) for example, termed nursing and teaching as 'semi-professions' due to the relative lack of autonomy and the large numbers of people who follow these occupations. Millerson (1964) attempted to define the term by compiling a list of 'professional traits', although this was itself criticised by Eraut as being based solely upon the author's view of the characteristics of high status professions such as medicine and law. Johnson (1972, 1984) approached the concept of professionalism as an ideology, and professionalisation as the process whereby occupational groups seek to gain status and advantage in terms of this ideology.

Training in veterinary medicine is highly regulated both by the university system and also by professional associations (the Royal College of Veterinary Surgeons, or RCVS, and the British Veterinary Association, or BVA). Research in the (human) medical sociology field has emphasised the role of aspects of such training and regulation in socialising young doctors into the culture of medicine, so maintaining the status quo in relation to a powerful profession's exclusive right to practise, (see for example, Atkinson and Heath 1981). In contrast however, the training for sculpture, as is the case with many other artistic pursuits, is far less rigidly structured and regulated. Whilst it may last as long and be as structured as that undertaken by veterinary surgeons, this is not necessarily the case. On the contrary, given the lack of formal regulation, it may follow any number of alternative patterns. Indeed, some practitioners claim never to have undergone any formal training whatsoever. My own respondents varied according to the type / length / form of training they had received, from art school degree to some sort of formal or informal 'apprenticeship' in which they learned by working alongside experienced people in some similar or related field.

There are doubtless many other criteria by which these practices could be categorised ; these merely serve as examples. However, instead of consigning them separately into (roughly) arts and science, or 'professional' and 'non-professional' (or for that matter, any other) categories in a classificatory (dualistic?) sort of way, I wish to concentrate instead rather upon the things that they have in common.

1.5 ... And narrative order...

I began this chapter with a quote from Fodor, with which he incidentally also began his work *Representations.* As I recollect, he then followed this comment with a very long introduction to his book. I do not entirely recollect to what extent he managed to avoid either superfluity or prematurity in doing so. However, in making this statement Fodor identified a problem which is very relevant to the present work; how very difficult it is to 'begin' writing a project of this nature. It could be assumed that one might start at 'the beginning', for example by stating what is to be covered, and work forward from this in a step-by-step sort of fashion to the conclusion. It is by no means clear though, where 'the beginning' lies when considering in more depth the matters that form the focus for a complex study such as this (or for that matter, that of Fodor). Any starting point is in a sense arbitrary. Also, although it is fairly straightforward to identify *what* they are, it is not at all obvious precisely *in which order* should fall the various 'steps' which logically follow it. In fact, it is most difficult to position them in such a tidy, serial order, simply because life as it is lived (as opposed to life as it is (re)constructed) does not usually consist of, and neither does it result in, such order.

In reality (as opposed to situations which occur in the narratives, or 'stories' that we tell about it), several things may (indeed usually) happen all at once, so that it is difficult to tease them apart in order to recount them. Moreover, events do not necessarily follow a *pro*gressive pattern, but may *re*gress. For these sorts of reasons, we cannot 'tell it like it is' in any real sense. There are always many alternative stories that could be told (Bennett and Royle 1999). We are faced with a task not of straight reporting (since this is not possible), but of construction, (or reconstruction) of events into a narrative sequence.

1.6 Narrativity....

'We are made real by stories'
Curt 1994, p.55).

Already, 'words have failed me' in several respects as far as the things that I am trying to communicate are concerned. The main reason for this I think, is inherent in the narrative form itself, which I am compelled to use, both for reasons of convention and also because of the lack of any *real*istic alternative. (I refer here to Curt's quote, cited above). Narrative is useful (even essential) to us because it helps us to order, communicate and make sense of our experiences (Johnson 1987, p.171). Narrative enables our readers (or hearers) to imagine a situation - that is, to create a mental image of what is happening to us, or what we are doing. However, like all representational forms, it also has its limitations, and these lie within these very processes of ordering, communication and sense-making.

A narrative is in an important sense, a (re)construction of our lived experiences, which requires additional reconstruction (or interpretation) by our readers or hearers (Atkinson 1990). Paul Atkinson referred here to *ethnographic* narratives (such as those featured within this thesis). He called these 'highly contrived products'. This was not intended as a particular slur on the methods of ethnography (which is after all Atkinson's preferred method of enquiry, as well as my own), but rather to emphasise some general limitations; principally in so far as ethnographic writing, in common with any other type of account or representation, cannot possibly be neutral or 'objective' in any accepted sense. Atkinson described in detail how narrative order is '*an accomplishment of tellers, hearers, writers and readers*' (ibid p.105); for example in the 'writing down' and the subsequent 'writing up' stages that one goes through in order to produce an ethnographic monograph. One initially 'writes down' one's field notes (which are themselves reconstructions or interpretations of what the observer has seen), and eventually 'writes them up', in a process which again reconstructs and reorders these into a coherent narrative.

Atkinson described strategies within these narratives by which ethnographers 'place' the reader at the scene, and additional rhetorical devices such as the use of paired clauses in titles to link a specific topic to a more general theme or theory. This denotes that the piece of writing under consideration is about 'something more than' the author's own study (ibid pp.76-80), and is common within the genre; narrative possesses also then, a persuasive, or rhetorical function. I have used the latter convention myself - '*Mapping surgeons' mapping the body.....*' These aspects are discussed in more detail in Section 2 of Chapter 6, which relates more specifically to methodology. Narrative sequence has failed me again - or (very possibly) vice versa.

Gooding (1990, 1996a, 1996b) highlighted another drawback inherent in narrative recounting. He showed how many of the things which are for one reason or another difficult to articulate, tend to get 'lost' within narratives. Whilst recognising that reconstructive processes such as those involved in *narrating* (as we could term the production of narrative accounts), have great value in that they are ordered enough to enable further action, provide clarity of communication, and allow the redefinition of problems, it is important to take on board the fact that they also have important constraints, as narrative accounts of scientific experiments have shown. These constraints are often to do with ways in which skills are rendered invisible because aspects of them cannot be verbalised (Gooding 1990, p.27). Even those aspects which *can* be explicated tend to lose this visibility as observers or experimenters gain in expertise, and the skills themselves move into the realms of the tacit.

Gooding (1990) criticised philosophers' neglect of the epistemic significance of the way in which 'actions' are subsumed as 'statements' in scientists' published accounts of their work. Although the reflexive nature of experiments enables understanding, their reporting often involves translating actions into statements, which are propositional in nature. Action can be expressed in propositional (and many other) forms though, only in hindsight, and this does not reflect the inherent 'messiness' and immediacy of experimental reality. Gooding went on to show how this correspondence of words and images to things and processes is a *made* relationship (ibid, p. 160). As we will discuss later, much research in psychology, science studies and artificial intelligence has shown that it is misleading to identify knowledge only with what can be expressed in words.

The narrative form then, imposes a serial order, a sequencing of events quite unlike what actually happens in reality (Gooding 1996a, p.82). Thomas Nickles (1988, p.34) has also criticised many philosophies of science for their unquestioning acceptance of what he termed this 'one pass fallacy'. By this he meant the way in which scientists' written accounts of their work give the impression of a single, linear 'pass' or string of operations, thereby obscuring and ignoring to a great extent both the problems and uncertainties encountered along the way, and the creativity necessary to solve (or at least work with) them. One reason for this may lie in the fact that creativity is difficult (indeed almost impossible) to recognise as such after the creative process has ended (Gooding 1996b, p.191). Gooding described how creative insight can elude introspection, since before its completion, it does not necessarily appear to be creative. Often it seems to be going nowhere, or alternatively in too many directions all at once. The linear, unidirectional nature of narrative conceals the reality of human creative (and recreative) processes (Gooding 1996b). While his arguments were situated in terms of discovery in innovative science, my own belong within more commonplace discovery. Although situated in far less exalted spheres, such small 'discoveries' are interesting in that they are common to skilled practice and to all of us.

In order to aid with their communication, I produce my own images (*Graphic renderings)* which I use alongside the text. Like the images and text in the surgical manuals and anatomical atlases that my respondents use, both images and text are intended to be used together, each to compliment the other. As well as these works that are the stock in trade of my research respondents, I am influenced by the diagrammatic notation that dancers and choreographers use to communicate movement.[2]

The question that this research attempts to address is that of: 'How do surgeons map the body during operations?' I state below some broad objectives in relation to this.

- to consider the ways in which we apply knowledge in our approach to, and performance of skilled tasks
- to consider alongside this the role of physical images such as pictures, and our own mental visual images in skilled task performance
- to examine the ways in which people use two dimensional representations to help them carry out three-dimensional tasks, or solve three-dimensional problems
- to experiment with the use of text alongside alternative representational forms in the communication of process.

1.7 Thesis Plan and Layout

Before presenting my field work case studies, I conduct an interdisciplinary (though necessarily selective) review of the literature pertaining to *knowing* and *seeing,* in order to provide for my studies an appropriate theoretical, historical and practical context. This review is necessarily wide-ranging, since there exists no discrete 'body of literature' that pertains to the particular topics to which I refer. This is a 'science studies'- based thesis. I place myself philosophically (as well as geographically) within the science studies form-of-life. However, as well as traditional science studies sources, art and art history, history of science, sociology, philosophy, psychology, cognitive science and others are represented in my bibliography. The structure of the remainder of this thesis is as follows:

Chapter 2 **'Knowing'** discusses ways in which 'knowledge' has been defined and categorised, and compares two contrasting models of 'knowledge'; that implicit in knowledge acquisition methods used in Artificial Intelligence and Expert Systems, and an alternative, enculturational model based upon arguments put forward by a body of work in SSK (the sociology of scientific knowledge). I examine the role of knowledge within skilled practice, and review the ways in which novice practitioners differ from experts. Following on from this, I discuss the significance of plans for skilled practice. I conclude with a consideration of mapping as a way of knowing.

Chapter 3 **'Seeing'** begins by exploring the necessity for, and problems that exist with dividing these topics into discrete chapters and sections. I justify separation of the material in this chapter from that in the next with reference to Kantian distinctions between 'seeing as' and 'seeing that' (Miller 1996). Thus I discuss visual representations of the body here; in anatomical pictures, three dimensional models, and also what I have termed 'extra-sensory perceptions'. By this term, I refer to bodily images obtained by means of technologies such as radiography, and also to 'non-pictorial' representations such as the printouts provided by machines that quantify substances within the body (such as blood biochemistry analysers), or which enable the visualisation of minute bodily movements, such as the kymograph and its descendents. The latter two do not visualise the appearance of the body, but provide information relating to its function. Particularly interesting are instances in which numbers of these representations, often from different modalities, are superimposed, or juxtaposed together. I conclude by examining debates about our uses of mental imagery, and ponder the ways in which this impinges upon the uses that we make of its physical counterparts of the types already mentioned.

Chapter 4 **'Knowing and seeing'** follows on from this in its consideration of occasions when we move beyond our actual perceptions to make inferences about things in the world. I discuss the emergence of visual languages, not only as a tool for communicating ideas, but for thinking about them also. I consider in addition the different 'models' that exist of 'mental models'. I conclude with a discussion of modes of inference. I argue for the abductive model to account for the creative thinking of skilled practitioners in solving problems in their everyday work, and in dealing with novel or uncertain situations.

Chapter 5 **'Putting the language into visual languages'** discusses some of the ways in which the visual interfaces with verbal language. Notwithstanding the difficulties so far encountered with matters pertaining to language, particularly narrative sequencing, the importance of language to the topics under consideration cannot be denied. I discuss in particular the roles played by talk and text in the workplace, and the cruciality of metaphor and analogy to science and to art. I suggest that we use visual representations alongside verbal ones, sometimes together and sometimes separately, and interchangeably, and for the same purposes. I argue thus for the possibility of the 'visual metaphor'.

Chapter 6, **'How we got here'** is divided into two sections. In section 1, I summarise the main points that have been raised by the literature review, and reflect upon the nature of the research question. Section 2 is concerned with methodology, with an emphasis upon the method(s) of ethnography.

Chapters 7, 8 and 9 will consist of empirical material derived from my ethnographic work, to include case studies of actual procedures. I experiment with alternative forms of recording and communicating process (alternative, that is to the use of narrative alone).

Chapter 7 **'Building bodies...'** is an account of a small pilot study which involved interviews with (and observations of) four artists / craftspersons whom I have termed 'sculptors'. The purpose of this study was primarily to develop methodology. However, I justify its inclusion because it offers some interesting insights, particularly in respect of the uses of 2D pictures in the performance of 3D tasks (mirroring in some respects the uses that surgeons make of anatomical pictures).

Chapter 8 **'Taking things apart'** explores a common surgical procedure undertaken by vets, that of the 'spaying', or sterilisation of female domestic animals. I discuss ways in which surgeons categorise the operations that they perform, which may give clues as to how they think about them, and approach them. I describe the preparatory procedures that both surgeons and their patients undergo. In the case of these routine operations, it would appear that these are not always performed strictly in line with textbook guidelines, but tend to vary along with the experience of the surgeon. I identify 'primary enhancement', 'reduction, and 'further enhancement' procedures which are applied to the patient-body, in operations that proceed in a routine way, and also in an instance where a skilled surgeon experienced uncertainty in relation to an anatomical abnormality / variation that he had not previously encountered. I argue for the abductive model of inference as the best explanation available to account for his actions in this situation.

Chapter 9 **'Putting things (back) together'** examines some less routine surgical procedures, in the form of orthopaedic operations. Main concerns raised include expanded discussion of 'further enhancement procedures' and their use by different groups of surgeons in performing 'actual' and 'virtual' operations. The differences that exist in novices' and experts' approaches to a task, and between textbook accounts and actual practice are further highlighted. I discuss in more detail, and speculate further upon the roles of pre-operative procedures, both in relation to their uses as 'enhancement and reduction' tools, and also to Goffman's (1961) role theory.

Chapter 10 presents the discussion and conclusions to my study. It will discuss the findings of the case studies in relation to the research question, and consider their broader applicability. It will discuss the strengths and weaknesses of this research, identify other issues of interest that arose from the data, and make suggestions for further research.

NOTES

1 'Hardness' as in 'difficulty'.

2 Thanks to Mrs J. Vosper of The Corsham School, Wiltshire for information relating to this.

CHAPTER 2: KNOWING...

2.1 Introduction

'Speaking of the vexatious problem of whether these elaborate electronic brains could really 'think', Sir Ben (Lockspeiser) said that it was necessary to distinguish between routine thought - which a machine could often perform much more quickly and more reliably than the human brain - and creative thought, which lay outside of the province of the machine'.
'Electronic Brains'. Scientific Correspondent, *The Manchester Guardian*, 7 May. 1954.

When we are asked the question 'How do you know that?', it is usually in response to some assertion or statement that we have made. What we are actually being asked for is some form of evidence or justification to back up our assertion. In asking a similar question here though, what I am after is not how we know *one particular thing*, but how we 'know' in general. I could phrase this question differently: 'H*ow do we come to know anything?'*, or alternatively *'How do we know what we know?'*.

In this chapter I will explore some of the (alternative) answers that could be put forward to such questions. I begin by discussing a range of definitions and classifications pertaining to 'knowledge'. I continue with a comparison of two broad traditions that have been put forward as to its nature; that (arguably more 'traditional' one) implicit in knowledge elicitation for Artificial Intelligence and Expert Systems research, and an alternative model based upon arguments put forward by a body of work in SSK (the sociology of scientific knowledge). These traditions need to be borne in mind in relation to ideas discussed further on in this chapter, and elsewhere.

Although I discuss visualisation more fully in ensuing chapters, I briefly mention here also concepts of 'seeing', perception or observation which are associated with these models of knowing. I include this here in my anxiety to avoid inferring (by separating them totally in a *physical* sense) any separation (in a more *philosophical* sense) between knowing and seeing. After Wittgenstein (1953) and Hanson (1965) I argue *against* the conventional hierarchy which places cognition above perception (eg see Fodor 1983), and *for* the inseparability of knowing from seeing. As Barnes *et al* (1996, p.4), writing from a science studies perspective put it, for me, '*observation ... is shot through with interpretation'*. However, I am restricted by the narrative form that I am trying (somewhat unsuccessfully) to escape, and the associated necessity to 'sequence' this thesis by dividing it into discrete chapters.

I continue by examining the notion of 'skill' as distinct from that of 'knowledge', and considering the role of knowledge within skilled practice. I review also 'stage models' of skill acquisition, particularly in relation to the ways in which 'novice' practitioners differ from 'experts' in task performance. Following on from this, I discuss the significance of plans for skilled practice. It is accepted in a common-sense sort of way (in our society at least - there are other interpretations possible), that people plan their work, either meticulously, or in a rough and ready sort of way, perhaps depending upon individual factors such as 'personality', or alternatively upon the kind of task being undertaken. One could assume that herein might lie a verifiable difference between the sciences (however applied) and the arts. My chosen example of surgery would seem to be one in which meticulous and careful planning is essential. It might after all be a matter of life and death literally that things go strictly according to plan; if plans go wrong, or have to be changed due to unforeseen circumstances, the consequences might be grave indeed. It is contended however, following Suchman (1987) that although people's attitudes towards planning are largely dependent upon cultural factors, we in fact all use (and do not use) plans in a similar sort of way. I conclude by considering 'mapping' as a 'way of knowing'. This theme is revisited in the following two chapters in connection with various related topics.

This chapter has obvious (and explicit) cognitive and social dimensions. What is not necessarily obvious, is that knowledge also has *physical* dimensions. Some examples might include the various means by which knowledge is encoded and communicated, in books, papers, instruction leaflets, recipes, diagrams, plans, computer programs and so forth, and also ways in which these are applied or used in practical activities. The physical dimensions of knowledge are therefore equally as important to this study as those others mentioned above. As we later see however, any or all of these dimensions may be obscured in certain ways, due to the difficulties that lie in specifying some of the contents of knowledge.

These are huge topics, and I have necessarily been selective in so far as I review only some of the sources which would seem to bear direct relevance.

2.2 What *is* knowledge?

This is a question which has caused great concern to psychologists, philosophers and others over many years. Different, and contested models of 'knowledge' exist, but as yet there is no consensus as to which (if any) is the 'right' one, which may go some way towards explaining why teaching is so very difficult, and learning still so poorly understood (and incidentally perhaps, why education remains such a hotly contested topic in academic, political and other arenas).

'Knowledge' (although a familiar concept, and one which everyone knows about in a common sense sort of way), lacks a single, uncontested and overarching definition. Regoczei and Hirst (1992, p.14-15) summarised some of the alternatives that exist, and also some of the problems that these definitions entail, in relation to their own field of Expert Systems research. They defined it firstly as 'a concept consisting of a cluster of associated metaphors', and went on to describe some of these metaphors, the ways in which they can be useful, and the ways in which they are sometimes misleading; for example, knowledge as a (metaphorical) substance that people possess, and which can be (however problematically) transferred from one person to another, or stored in a database (after Reddy 1979), and knowledge as a sort of organic being, (think about the way people talk about the 'creation' and 'growth' of knowledge). Aside from these 'metaphorical' definitions (metaphor will be revisited in ensuing chapters, particularly chapter 5), Regoczei and Hirst also cited the common sense idea of knowledge as 'justified true belief'. However, there are snags related to this, not only for their own field but also more generally; the practical difficulties of operationalising or eliciting 'beliefs' for example, and (perhaps more philosophically) the contrasting and conflicting ideas that exist regarding the terms 'justify' and 'true'. Whose justification, and whose truth? Who decides?

Newell (1982) identified knowledge with goals, aims, objectives, plans and purposeful behaviour. This seems useful, and to a certain extent, I make use of this definition here. However, as Regoczei and Hirst (1992) pointed out, there are other 'knowledges' possible, that may not be consistent with goals and aims; ethical, holistic or aesthetic knowledge for example, which may not be valued so highly in our society as more analytical, 'scientific' kinds of knowledge, but are nonetheless undeniably very important in some domains of expertise. Therefore, as a single, overarching definition it might still not work. Newell and Simon (1972) saw knowledge as a form of writing-like representation inscribed in the mind of a cogniting agent (which might be a human, or a computer). This definition of knowledge, as a representation of something in the world, is also one that is useful to my arguments, and one also I feel, that can include the 'alternative' kinds of knowledge alluded to above. I remain unsure however why it should be encoded in writing-like form; why not as images for example?[1]

So much for definitions; various attempts have been made also to classify knowledge into different types, or categories. Regoczei and Hirst (1992) summarised some of these as follows:

- Personal knowledge; that possessed by the individual. This is made up, partly of the general body of public knowledge of the culture to which the individual belongs (for example, knowledge about surgery), and partly of that individual's own store of experiential, contextually applied knowledge which has been built up over time.
- Public knowledge, consisting of rules and techniques (such as that published in anatomical atlases and surgical textbooks), pertaining to a particular culture or form-of -life. This socially constructed knowledge may not be public in so far as *everyone* knows it, but it is in the public domain of the particular culture to which it belongs.
- Objective knowledge; this could be construed as 'factual' knowledge, 'the truth', or 'independent knowledge[2]. This type of knowledge is regarded very highly in our society, and forms a basis for the 'hard' sciences such as mathematics and physics.

All three of these types (or dimensions) of knowledge are of obvious importance in my research context. Another, related distinction is that between 'book knowledge' and the 'experience knowledge' that has been 'field tested' (ibid, p.17); refined, selected and improved in actual contexts. These classifications have been linked to the distinctions between task knowledge, or 'knowing how' and domain knowledge, or 'knowing that', (see Ryle 1949; Polanyi 1958; Buchanan and Smith 1989 for further discussion of these terms). At various times, this distinction has been referred to as procedural versus declarative, or propositional or formal knowledge versus experiential, (eg Anderson 1983; Cooke 1992). Anderson's (1983) theory of skill acquisition (described in more detail below) is largely based upon proposed changes in declarative and procedural knowledge systems which occur as expertise is gained.

Regoczei (1992) questioned the usefulness of this procedural - declarative dichotomy, arguing that these two knowledge 'types' cannot be so easily separated. Task knowledge for example can be represented in both declarative and procedural ways. For example, declarative knowledge can include knowledge about procedures (as in knowledge about the steps required to successfully carry out some task). This argument too has obvious relevance here. However, this (verbalizable) 'knowing' knowledge versus (non-verbalizable) 'doing' knowledge distinction is nevertheless a useful one in terms of my arguments, although as Regoczei intimated, it may not be particularly useful to think of them in terms of a strict dichotomy. Collins (1990), argued against the very existence of different categories of knowledge. For Collins just one sort exists, and any apparent distinctions or differences are to do rather with the different ways in which we deal with it. He stressed that 'knowing' and 'doing' (like knowing and seeing) are not so easily separable, and that we demonstrate those parts of what we know that cannot be stated through the ways in which we act. He also pointed to the fact that what is or is not verbalizable does not remain constant, but shifts across time and social circumstances. As he put it, the non-verbalizable becomes verbalizable at such times as 'craft is made explicit by scientific research' (p.112).

Hatt (1995) studied contradictions that exist between formal and experiential parts of knowledge in a clinical setting not entirely dissimilar to that which forms the main context for this study. She attempted to address how physicians relate their formal, clinical training to the reality of specific clinical contexts, and found that they continually experienced (and had somehow to come to terms with) uncertainty. Formal, 'textbook' knowledge was frequently contradicted by actual experience. According to Hatt, this highlighted the incompleteness and inadequacy of the rule-specified part of medical knowledge. As my own data show, clinical uncertainty forms part of the everyday experience of surgeons. Far from being wholly negative however, it allows the emergence of the potential for creativity (and evokes behaviours) similar to that shown by scientists working at the forefront of what is known within their disciplines (see Gooding 1990; Nersessian 1992).

Knowledges may also be 'classified' according to their particular function (strategic knowledge, planning knowledge). Such classifications address the question 'How are they used?' rather than that of 'What are they?' (Regoczei and Hirst 1992, p.17). One type of knowledge that every human being (but conversely, no machine) is supposed to possess to some or other degree is the tacit, contextual and embodied sort of knowledge that is required for temporal and spatial reasoning (Johnson 1987). This knowledge is implicit in being human, (and as such part of society), and possessing a body that can experience things. Clark (1997 p.X11) expressed a similar viewpoint (though from a rather different disciplinary stance). He argued that the brain and the mind are 'embodied and embedded', and that rather than being studied in isolation, as is common in some schools within psychology and AI, it should be studied in conjunction with the rest of the body and its local environment. Such arguments have obvious implications for the matters discussed here.

I next turn my attention to two broad traditions of thinking about knowledge, an 'enculturational' model (Collins 1990) put forward by a body of work in SSK, and the 'individual psychological' or 'algorithmic' (ibid) one implicit in knowledge acquisition methods for AI and Expert Systems. These traditions are themselves underpinned by different conceptions of the nature of 'seeing', and also learning.

2.3 The 'enculturational (or apprenticeship) model' of knowledge

I consider first of all the tradition which centres upon arguments put forward by a body of work in SSK, in which skills and their transmission are seen as social phenomena. These arguments, broadly, see scientific knowledge as socially constructed, and as the collective property of a culture or 'form-of-life' (after Wittgenstein 1953; Winch 1958), rather than as residing in individuals. Collins (1974, 1975, 1985, 1990) showed how the ability of a group of scientists to build a laser of a certain type depended upon their being part of a skilled community of laser builders, and having extensive personal contact with them. Spoken or printed instructions alone could not enable them to solve the problem of making this laser work.

Collins explained this in terms of the possession by this particular scientific community of traditional knowledge which could not be explicated (at that time) because they neither knew they had it, nor understood its significance. Collins termed this the 'enculturational or apprenticeship model', and I borrow his terminology here. An example of this way of thinking about knowledge that would be familiar to almost all of us, is to consider the situation of a novice cook (one's child for example). My younger daughter sometimes tries to follow the recipes in my cookery books. However, without extensive assistance and lengthy explanation she is often unable to do so with any degree of success, due to her relative inexperience of cookery. (What does 'fold' mean? How brown does it have to be when it just says to 'brown' something?) This is despite the fact that, as a bright teenager she would seem to possess the required skills. She is for example a proficient reader of recipes and other written material, and adept at the sort of mathematical skills required for measuring ingredients and converting between imperial and metric weights and measures.

Barnes *et al* (1996 p.27) spoke of the importance of *'local scientific cultures'* for both the initial establishment and the subsequent transmission of scientific knowledge. They argued that the possession of similar *interpretations* of observed phenomena is a key factor in such a model of scientific knowledge and its acquisition. Following Hanson (1965), they denied that perception and interpretation can be separated; in effect therefore, to see (or observe) something is to interpret it, a *single* process. They argued further, after Kuhn

(1962), that interpretive traditions in science (as in other domains) are *'largely inherited from others, shared with others, validated by others and sustained in the course of interacting with others'* (ibid p.26). According to this tradition therefore, what you see (and therefore to a large degree what you 'know' about it) is mainly dependent upon what those around you see. For as Collins (1990 p.4) put it, *'the same appearance can be seen as many things'*.

MacKenzie and Spinardi (1995), argued that skills die out if they cease to be practised due to the disappearance of the cultures upon which they are based and within which they are transmitted. They predicted the demise of nuclear weapons because of international agreements in force at the time banning their testing. Testing is apparently so integral to the design process of atomic weapons that, should it remain impossible, the ability to design them would die out along with the culture of weapons makers that sustains it. 'Testing' has now moved into the realms of simulation, which begs the question of whether cultures of weapons-testing simulators will work (or behave) in the same way[3]. Such arguments are not limited to scientific contexts. On a rather more mundane level, Orr (1990) stressed the importance of what he termed 'community memories' to a service (as opposed to a scientific) culture, in his study of office equipment repair technicians.

This tradition of thinking about skilled practice is underpinned by an 'apprenticeship' model of learning. People become skilled cooks, carpenters, plumbers, motor mechanics and surgeons by watching, working and interacting with other people who already have these skills. We in effect become immersed in an occupational culture (and in doing so, gain occupational skills) over a period of time. Apprenticeships for skilled trades, and also (very relevantly) the 'clinical experience' undertaken by student medics (see Atkinson and Heath 1981), or 'seeing practice' as it is termed in the veterinary form-of-life, provide examples of training informed by this model of learning.

An important implication of this is that it is not possible to become a skilled practitioner simply by being told facts, although the gaining of factual knowledge by such means certainly allows us to access some components or aspects of the required skill. Pinch, Collins and Carbone (1996), whilst upholding the principle that skills and their transmission are social in nature, wished to address questions relating to how such knowledge is explicitly transmitted and acquired as part of learning a skill. Such questions are not fully addressed by the enculturational model. We know that this transfer of knowledge somehow occurs, and whilst it is certainly not the full story as far as becoming a skilled practitioner in some or other domain is concerned, whole educational systems are after all built around this concept (or at least the ideologies underpinning them are; I would argue that educational *practice* is somewhat different). We study textbooks, consult computer databases, visit websites and attend classes in order that we may gain such knowledge. Moreover, such activities are highly regarded in our society. This necessarily brings us to consider an alternative model.

2.4 The 'individual cognitive', 'psychological' or 'algorithmic' model (Collins 1990)

The second tradition concerns arguably more traditional and taken-for-granted individual 'cognitive' or 'psychological', (as opposed to 'social') theories and explanations of knowledge and its acquisition. This 'common-sense' model is implicit in knowledge elicitation methods used in Artificial Intelligence (AI) and Expert Systems research (eg, see Hoffman 1992). Attempts are made by researchers in these fields to 'collect' the accumulated knowledge of experts in order that it may be encoded and transferred to a computer, thereby rendering this knowledge accessible for use by others who are not necessarily experts themselves. In the course of such attempts, (which it must be said, have varied in the degree of their success), it has been necessary for practitioners in these disciplines to think long and hard about what knowledge is and how it is used, quite apart from other, related questions such as methods by which it can best be captured or collected.

Knowledge capture is attempted by means of observations, interviews and 'verbal protocols' in which experts in a given field are asked to 'speak aloud' about what they are doing as they perform a given task. This technique is derived from introspectionist methods once popular in psychology although more recently treated with a certain amount of caution, due among other reasons to perceived 'subjectivity'. This is addressed more fully in chapter 6. However I will argue that *all* research methodology is 'subjective' to a greater or lesser extent, and that both researchers and their readers need always to keep this in mind. I reiterate; to *observe* something in some or other way is to *interpret* it, to relate it to one's personal framework of representations, concepts and assimilations.

The main problem with this model (as far as knowledge elicitation for expert systems is concerned; my own objectives are considerably more modest) is the underlying assumption that an expert can explicate all of his/her knowledge 'to order' in such a fashion. It has on the contrary been repeatedly shown that only *some* of an expert's knowledge becomes accessible by such means (see Dreyfus 1992 and Hoffman 1992 for discussions relating to this problem, albeit from rather different standpoints), and that this limits the usefulness (and ultimately the use) of the resulting programs. This is not to say of course that they are entirely without use. However, they are only of use up to a point, and far from being a tool which enables novices to utilise the knowledge of experts, they in fact require a good deal of (expert) human input and 'repair' (Hartland 1993) in order to be effective. Thus computer programs cannot totally replace either the diagnostic skills of physicians (Blois 1980) or the operating skills of surgeons (Rooke 1994), just as Collins' embryonic laser scientists could not by themselves build a working laser, because they all lacked certain critical elements within expert knowledge which are for various reasons difficult to explicate, and can be got only through protracted immersion in a human culture.

Collins (1990) has termed this model of knowledge and learning 'algorithmic'. Algorithms are exact rules and formulae that can be specified to a receiving system (which may be a human mind or the 'mind' of a computer). A good example of such a rule is the formula for a long multiplication problem; so long as it is followed absolutely correctly, with no mistakes or deviations, the correct solution will be obtained *on every occasion*. However, algorithms are now recognised to be for the most part a cumbersome tool which is relatively little used in skilled practice, since as we have already discussed, human problem solving (outside of the psychology laboratory) tends to involve problems which are far too complex. Instead, people rely more often upon the use of less precise heuristics, or rules of thumb. These are not proven formulae in the same way as could be said of algorithms, and therefore cannot be guaranteed to work on all occasions. However, they *usually* work in practice nevertheless. Heuristics, as well as algorithms are now specified to AI programs, so labelling this model 'algorithmic' is perhaps a little misleading. Collins' concept of algorithmic knowledge acquisition however provides a useful contrast to the enculturational model that he also described. The model of 'seeing' associated with the algorithmic tradition of knowledge stresses the objectivity of the natural world, and takes it for granted that we see what is somehow 'out there' in an unproblematic and unbiased way. It has been used (many would argue rather uncritically) to 'explain' science, and characterise it as different from various other human discourses such as art and religion.

Heuristics can be formulated as 'production rules'. Sloboda (1986, p.23) drew attention to interest shown by cognitive psychologists in the possible role in skilled behaviour of 'associative pattern-action pairs'. These take the form of If-Then rules that can be applied to particular situations, eg, 'If condition X applies, Then carry out action Y'. Sloboda likened these rules in some respects to the S-R bonds used in behaviourist explanations of learning, although there are important differences. They are more flexible; X need not be a simple external stimulus for example, nor Y an overt behaviour. Such things as internal mental states and goals can also be included. Production rules can be incorporated into production systems; a set of rules sufficient for carrying out some task.

Production systems can easily be simulated on computer, and in fact form the basis for many AI programs (see Anderson 1983; 1993). They have also been used to explain how the knowledge of skilled persons may be organised, even that knowledge that is seemingly inaccessible until particular circumstances demand its use. Chase (1983) demonstrated how some types of knowledge may be accessible only when a particular situation demands it, in a study of US taxi drivers whose ability to actually *find* the best routes between two points in their city was shown to be greatly superior to their ability to verbally *describe* the routes in the laboratory. Learning can be explained in terms of the acquisition of new pattern-action pairs, and complex skilled behaviour postulated in terms of production rules used in conjunction with a goal stack stored in working memory (Baddeley and Hitch 1974; Hitch 1980). Other, related systems have been proposed for the organisation of knowledge (eg, schema theory (Rumelhart 1975; 1980), and scripts (Schank 1975; Schank and Abelson 1977; Baddeley 1990).

To label such theories as 'psychological' is not to say, of course that the *discipline* of psychology itself is devoid of cultural, or social explanations for knowledge and skills and their transmission. This is not the case. On the contrary there is a strong tradition within the discipline which places great importance on the role of culture in cognitive activities; see for example the work of Vygotsky 1931, 1960, 1978; Luria 1971, 1975a, 1975b; also Cole et al 1971; Cole and Scribner 1974; Cole et al 1997. However, it is probably true to say that the discipline of AI has been influenced far more by *cognitive* than by *social* aspects of psychology. For my own purposes (and arguably ultimately those of AI also), it may be the case that neither social, nor individual psychological (or cognitive) explanations on their own are sufficient to account for knowledge and skilled practice, but that both need to be considered together. As stated previously, *physical* aspects (Thagard 1999) for example the instrumentation, and also the images that surgeons use, must also be taken into consideration in any comprehensive analysis of this problem.

In any case, in novel situations, 'the rules' (no matter whether they are characterised as algorithms or heuristics) do not always apply, and then a practitioner must seek creative solutions based upon (but not identical to) situations that s/he has encountered in the past. Gooding (1990) called this novel, creative, problem-solving type of thinking 'construing', and situated it within an abductive model of reasoning. Closer still to my own research problem, Hatt (1995) has suggested that medics construct construals of what are novel phenomena *to them* to enable both themselves and others to understand their observations. This may be accomplished at least in part by means of visual representations. These aspects will be more fully discussed in later chapters.

It may prove illuminating at this point to examine in more detail the concept of 'skill', and how it differs from (and relates to) knowledge, if indeed it does.

2.5 What is 'skill'?

Much of the literature uses the terms 'knowledge' and 'skill' somewhat interchangeably, and indeed it is tempting to do likewise here. Up to this point, in fact, this is largely what I have done. However, it might now prove to be useful instead to give the term 'skill' some more individual consideration. Welford (1958) drew attention to the differing ways in which the concept is applied, for example in industrial settings, and in psychology. Skill in industry relates to the ability (usually acquired during an extended period of apprenticeship, or training), to carry out particular types of work which require knowledge, judgement, accuracy and manual dexterity, such as my illustrative examples of surgery and sculpture.

This can be misleading however, since many jobs and activities which are thought of in an industrial sense as 'unskilled', have been shown to be very skilled indeed, for example by Scribner (1997), who studied the 'practical thinking' of packers in a dairy product factory, and Saxe's (1992) studies of unschooled children who worked as street vendors. Despite their almost total lack of formal education, these children were easily able to carry out the mental arithmetical calculations involved in their buying and selling activities. These studies stress the contextual specificity of the skills under discussion. When transferred to the laboratory, tasks which appeared on the surface to be very similar to those undertaken during the course of their daily work proved to be much more difficult for the subjects involved. If the *context* were removed, then much of the *skill* appeared to be removed also. Schaffer (1997), writing from a history of science standpoint, stressed how 'skill' can vary according to various factors such as the site of the performance, the social role of the performer and the instruments used. Context then, is an essential framework within which skill is developed and applied.

In psychology, the term 'skill' is applied in a much wider sense, to cover for example the perceptual-motor skills used in taken-for-granted everyday activities such as walking and speaking, in addition to more complex skills such as those involved in driving a motor vehicle or using a computer. Whilst my own use of the term falls closer to Welford's 'industrial' notion of skill, it is useful nevertheless to bear in mind the broader psychological concept when thinking about these matters, for as Welford pointed out, the more complex, 'industrial' types of skills make similar though greater demands upon the nervous system. Fitts and Posner (1967) drew attention to the fact that skilled performance always involves an organised sequence of activities which may include physical movements and / or the processing of symbolic information.

Gellatly (1986, p.4) used the example of the relatively uncomplicated skill of sexing day-old chicks for the poultry industry, to illustrate the following features that are common to all skills:

- That skilled task performance may seem virtually impossible to the uninitiated
- That they seem to depend upon intensive practice; learning the task requires practical experience, and expertise is built up with further practice
- That they are dependent upon the specific social context in which they take place

Sloboda (1986) further listed the characteristics of skilled activities under the following five headings:

- Fluency; the parts of the activity run together in an integrated and uninterrupted sequence.
- Rapidity; appropriate responses to situations are made quickly.
- Automaticity; the skill becomes 'easy', and 'just happens' without us having to think about it.
- Simultaneity; complicated sequences of actions can be carried out simultaneously.
- Knowledge; not only in its possession but also in its being available at the appropriate time.

Sloboda then, located 'knowledge' as a component within 'skill'. I feel that this is a useful and straightforward way of thinking about the problem; certainly more so than treating the two terms as interchangeable, which I at least found somewhat confusing.

2.6 How we acquire skill, and become skilled practitioners: 'stage' models of skill acquisition:

I concentrate here upon debates that exist as to how we acquire knowledge and skills; in effect how we *become* skilled practitioners. This will entail discussion of the nature of expertise, the differences that exist between novices and experts, and the implications that all of this may have for skilled practice. This is important to my arguments because my (surgeon) research respondents varied considerably in the amount of task-specific experience that they had accrued, and showed corresponding differences in their approaches to particular tasks. I use the term 'experience' here in the Heideggerian sense of what results when preconceived ideas and context-free 'facts' are transformed by an actual context or situation. This is of course not as such directly related to the passage of time. However, it is probably true to say that longer periods spent in particular situations are likely to result in the accumulation of additional experience (and ultimately *expertise*) in these situations, hence the common sense connection made between time and experience. Expertise (like the nature of knowledge) is necessarily of interest and importance to those who work on the development of Expert Systems and AI programs. It comes as no surprise therefore, that the literature from these disciplines is of great relevance in its discussion. I am informed also by a considerable body of literature from psychology.

Several 'stage' models of skill acquisition have been proposed. An early example was that of Bryan and Harter (1899) who studied the development of skills in wireless telegraphy (the transmission and receiving of Morse code). According to such models, when acquiring a skill, we progress through stages from novice to expert performer, although it is fair to say that the boundaries between the stages are not well defined. One particular viewpoint sees the development of expertise changing in respect of changes in the practitioner's use of declarative and procedural knowledge (Fitts and Posner 1967; Anderson 1983, 1987; Rasmussen 1986). This model sees the development of expertise taking place over three identifiable stages, during which performers tend to move away from the use of declarative knowledge, more towards the use of perceptual, nonverbalizable procedural knowledge:

- Cognitive stage: characterised by the accumulation of declarative knowledge from various sources. If an actual task must be performed, relevant declarative knowledge is retrieved from long-term memory and operated on by domain-general procedural knowledge, or production rules (procedural knowledge that can be applied to declarative knowledge in any domain). Decision making is therefore slow and prone to error.

- Associative stage: as the practitioner becomes more competent in the domain, s/he moves into this second stage. Repeated use of declarative knowledge in given situations results in the accumulation of a bank of domain-specific procedures; direct associations between specific conditions and the resultant actions. Gradually the need to operate upon declarative knowledge is bypassed. When contextual conditions match the conditions of the procedural rule, the appropriate action is automatically invoked, thus avoiding the need to retrieve declarative knowledge and apply general productions to it.

- Autonomous stage: now the procedures become highly automatized, associations become stronger, and more specific. Procedural knowledge now works quickly and automatically. Simple productions become composed into more complex, inclusive ones. Because these compress a large number of instantiating conditions and resulting actions, they become difficult to verbalize. When this stage is complete, task performance requires virtually no cognitive resources, is autonomous, and unavailable to conscious awareness.

(Summarised by Gordon 1992).

A related stage model of expertise development was described by Dreyfus and Dreyfus (1986). This was developed from an earlier model (Dreyfus1979). In this model, (which I describe at some length because I feel it better describes the *behaviour* of learners than that summarised above, which is more concerned with theorising about the *mechanisms* that may be responsible for the actual progression), practitioners progress through not three but five stages from novice to expert performer. Dreyfus and Dreyfus described the stages is as follows:

- Novice: novice performers have no experience of the situations they are entering, and need to be given objective, measurable attributes which can be recognised without previous situational experience, and context-free rules to guide their actions in respect of these attributes. Behaviour is rule-governed, limited and inflexible in nature, since the rules cannot convey to the novice which tasks need to be prioritised in an actual situation. These facts and rules are valuable since they allow entry to the situation and provide opportunities to begin to accumulate experience. However, they must eventually be put aside if the novice is to progress.

- Advanced beginner: at this stage, the learner recognises similarities to previously encountered situations (or can meaningfully have them pointed out to him/her). S/he can therefore note the recurrence of meaningful aspects (situational now, not context free) on other similar occasions. Behaviour now encompasses situational as well as context free elements. Such aspect recognition takes a lot of time and the advanced beginner still has to 'remember the rules'.

- Competent: at this stage, a performer has experience of similar, previous occasions, and sees a situation as a set of facts. He or she begins to see his or her actions in terms of long range plans or goals. These plans dictate which aspects or attributes of a situation are most important or urgent, and which can be ignored or postponed. He or she understands and decides upon courses of action in a detached manner, reflecting upon various alternatives. The behaviour of competent performers can be characterised as 'problem solving' behaviour.

- Proficient: such performers intuitively understand and organise the task in hand (based upon previous experience) but still think analytically about what action to take. Memories of past situations trigger plans similar to those that worked in the past, (resulting in periods of involvement in the situation followed by detached decision making).

- Expert: expert performers do not plan, and do not make decisions, they just do what normally works. They will however deliberate before acting in crucial situations, or where time permits, often in a critically reflective way. Over time they will have built up a 'library' of distinguishable situations which can't all necessarily be described or even remembered in words. Situations are seen as similar to a prior one, and actions and decisions undertaken on the basis of this, and simultaneously. Experts may describe or justify this in terms of hunches or feelings about something.

(Summarised from Dreyfus and Dreyfus 1986, pp. 21-32; and Benner 1984 pp. 20-34)

Behaviour in relation to these various stages has been analysed by Benner (1984) in an influential work on the training of nurses in human medicine, and I have myself observed it in relation to the acquisition of veterinary nursing skills (Woodgate 1998).

2.7 The differences between novices and experts:

A body of research has shown that the knowledge *structures* (ie, the ways in which knowledge is organised) of experts differ from those of novices in a number of important ways. It is not simply a matter of experts having *a greater quantity* of knowledge at their disposal than novices. Studies of expertise, principally in games, have cast considerable light upon this. Charness (1979) showed how skilled problem solving in bridge depends upon the possession of what was termed a 'large vocabulary' of meaningful (for the game) and recognizable patterns, associated with the appropriate actions that need to be taken; in other words a detailed production system for the game. Chiesi, Spilich and Voss (1981) explained the acquisition of knowledge in a particular domain (in this case baseball) in terms of its being mapped onto existing knowledge structures; therefore the more knowledgeable a person is about a domain, the easier it will be for him or her to acquire new knowledge about it. This has obvious relevance here.

Chase and Simon (1973) argued that the superior ability of chess Masters lies in their ability to perceive structure in meaningful positions, and encode them into larger perceptual 'chunks' in memory than can less skilled players. What is more, the chunks themselves may relate to each other in more abstract ways in the case of experts. Similarly, Chi, Feltovich and Glaser (1981) showed in the context of physics how novices and experts represent problems differently right from the outset. The representational strategy of experts was shown to be far more abstract, and less concerned with the mechanics of actual equations than that of novices. McKeithen *et al* (1981) demonstrated how expert computer programmers used domain-related strategies for the memorization of new material (encoded in programming language), whereas novices used more general mnemonic techniques, and intermediate performers used both. Expert knowledge is then, qualitatively (as well as quantitatively) different from that of novices, and expertise is above all specific!

2.8 The significance of plans:

The Dreyfus (1986) model of skill acquisition makes particular and explicit mention of the importance of planning at some stages of skill acquisition, notably the 'competent' and 'proficient' stages. However, performers at all skill levels will plan where time and the situation allows. Schank and Abelson (1977) identified plans with goals and 'scripts' (related to Minsky's concept of frames, and also schema theory (eg see Rumelhart 1980) as a means by which knowledge about particular situations may be organised. According to Schank and Abelson (1977), scripts allow us to take for granted certain items of information in a particular context. We acquire for example scripts for visiting a restaurant, attending classes, consulting a doctor, and other familiar social contexts. Merely specifying a particular context allows the appropriate script to be invoked. This allows certain things about the context to be 'taken as read'. Schank and Abelson described how scripts are made up over time of plans and sub-plans that are used repeatedly.

That we use planning, especially in relation to complex problem solving is fairly unproblematic. The problem lies in our perceptions of just how we use it, and how experts can apparently by-pass it in some situations. Suchman (1987) argued that our attitude towards planning is largely a cultural phenomenon, using Gladwin's (1964) example of navigation methods in the European and Trukese (a Pacific Island culture) traditions to illustrate two contrasting views of human purposeful action. Briefly, in the European tradition, the navigator begins with a formal plan (a charted course), and during the ensuing voyage, every move is related to that plan. Every effort is directed to remaining 'on course', and should unexpected events occur, the plan (course) must be altered. The Trukese navigator on the other hand begins not with a plan or a course, but with an objective, which s/he sets off toward, responding in an *ad hoc* sort of way to environmental and other conditions as they occur. S/he reacts according to information provided by many facets of the environment. His / her effort is directed towards doing whatever is necessary to reach this objective. The navigator, if asked, could point toward this objective at any time during the voyage, but could not describe 'the course' in the European sense (after Berreman 1966, p.347).

According to Suchman, the European model is to a great extent conceived as being context-independent (or 'cognitive'), and uses an abstract, analytical type of thinking, whereas the Trukese thinks in a less abstract, and more context-situated way. Suchman argued that these ways of thinking (or more to the point, these *models* of human thinking and purposeful action) are culturally learned. Great store for example is put in our society (but not always necessarily in others) on analytical, 'scientific' styles of thinking, as demonstrated by our navigator example. However, Suchman's argument is that *every* purposeful action is a 'situated action', in that it is inevitably placed in a very particular spatial, temporal and cultural context, which directs and influences our thinking and behaviour *on that, (and only that)* occasion. I would argue that neither model of navigation is complete. It could be said that both models in effect do both of our navigators a great disservice, conferring upon our European an inflexibility and a rigidity which would undoubtedly place those who venture to undergo a voyage with him or her at great peril given the vagaries of winds, tides, currents and so forth, and suggesting that our Trukese navigator works in a completely undisciplined and haphazard way which negates his or her many years of apprenticeship served in the craft.

According to Suchman's argument therefore, plans cannot and do not work as definitive 'recipes' for carrying out a procedure, in such a way as I was taught to write the methods section of a biological paper (so that another biologist, in another time and place, could exactly repeat my experiment or investigation), but on the contrary they lack fine detail, and are thus inevitably prone to change and adaptation. Just like the methods sections in biological papers in my experience!

I can personally vouch for the veracity of this, since this thesis has been planned, replanned and planned yet again on numerous occasions, and each time this has happened, the 'plan' has changed, sometimes a little, sometimes a lot. What is more, it is still changing, and I expect these planning and replanning processes to continue until the work is completely finished; all of the reading, the trips back into the field to ask yet more questions, and especially the writing. That this planning has had to be revised over and over again is not to say that the original plan was necessarily 'wrong', or that the planning process itself has not been useful; on the contrary it has been very useful indeed. It helped me first of all to make a start, and has subsequently helped in refining and redefining my ideas. In short, it has been a very valuable *tool.* It cannot however in any sense be thought of as any sort of an *explanation,* either for how this particular thesis was written (or as I would prefer to say, borrowing a term from several of my subjects, how it has *evolved*), or for how to write theses in general.

Knowledge then, can most usefully be thought about as a component of skilled, situated practice. I now move the discussion forward to consider more carefully ways in which knowledge (in this sense) may be represented, and form links between what has been discussed in this chapter, and matters which will be addressed in the following ones. I begin by outlining one of the ways in which knowledge can be communicated, encoded, and expanded. I refer specifically to the use of maps.

2.9 Mapping as a way of knowing...

The communication of knowledge about objects and their relationships in geographical space is not a straightforward matter. It may be done *verbally,* via the uses of directions, or spatial relational terms which situate a target object in relation to a reference object. Carlson-Radvansky and Irwin (1994) showed how language may be co-ordinated with perception in this way, and this analysis is interesting in that my surgeon research collaborators use their own form of spatial-relational language. Veterinary anatomical directional terms are shown in Figs 1-1 and 1-2 on p.42, and will be encountered in excerpts from fieldnotes in chapters 8 and 9.

As also shown by means of this diagram, communication about such matters can also be achieved by the use of *visual* representations, such as maps. This does not mean that the two are mutually exclusive, or that maps cannot be used together with language. Indeed this frequently happens. Merely producing a map in a location where there are other people present often prompts social interaction, discussion and communal perusal of the map. Like so many of the others discussed, mapping is a social, as well as a cognitive and physical practice (and as I will later show, this counts for anatomical, as well as geographical mapping). Neither do I mean that maps are *merely* tools for the communication of these types of information. They can do far more than this. As well as for orientation or navigation purposes, they can also be used for planning interventions (Beaulieu 2000), supporting knowledge claims (Alpers 1983), or as Camerini (1993) described, as tools for theory development. Tools, in effect, for thinking.

Camerini (1993) explored how mapping practices are used in this respect, in the context of the history of science. According to her arguments, the evolutionary theorists Alfred Russell Wallace and Charles Darwin made maps which, in their very construction, were instrumental in the *construction and development* of their theories, as well as in their *dissemination*. Camerini (ibid, pp700-701) identified the following functions of their mapping of the boundary between Asian and Australian faunas:

- To help organize and communicate their data
- As a potential device for predicting the range limits of other species (using their empirical data to theorise about other cases)
- As a means of argument and representation that was familiar to their peers
- As a method of analysis that 'tested positively' with their evolutionary hypotheses.

Camerini wrote, ' *Maps served (Wallace) as a conceptual framework, a metaphor and a tool for synthesizing and communicating his results- they were the actual and mental space on which the processes of biological, geological and geographical change formed a comprehensible pattern'.*

Wallace's maps (both physical and mental) of faunal regions served therefore as instruments of both thought and persuasion. This calls into question the nature of the boundary between the 'physical' and the 'mental'; of where physical imagery might begin for example, and its mental counterpart end. My attempts to construct a coherent narrative dictates that this discussion be continued elsewhere - from debates about knowledge and knowing, I have digressed; wandered (or blundered perhaps) into others, about the nature of seeing, and imagery.

To summarise, I have considered various debates as to the *meaning* of the term 'knowledge', and examined two broad traditions as to its *nature*. I have concluded that neither of these traditions is sufficient on its own to address the problems under investigation here, but that both have something to contribute. After Sloboda (1986), I have located 'knowledge' as a component within 'skill'. I argue for the value of 'stage' models of skill acquisition, and for the importance of social and physical context in the exercise, development and communication of skills. All of these points are of considerable importance to what will follow.

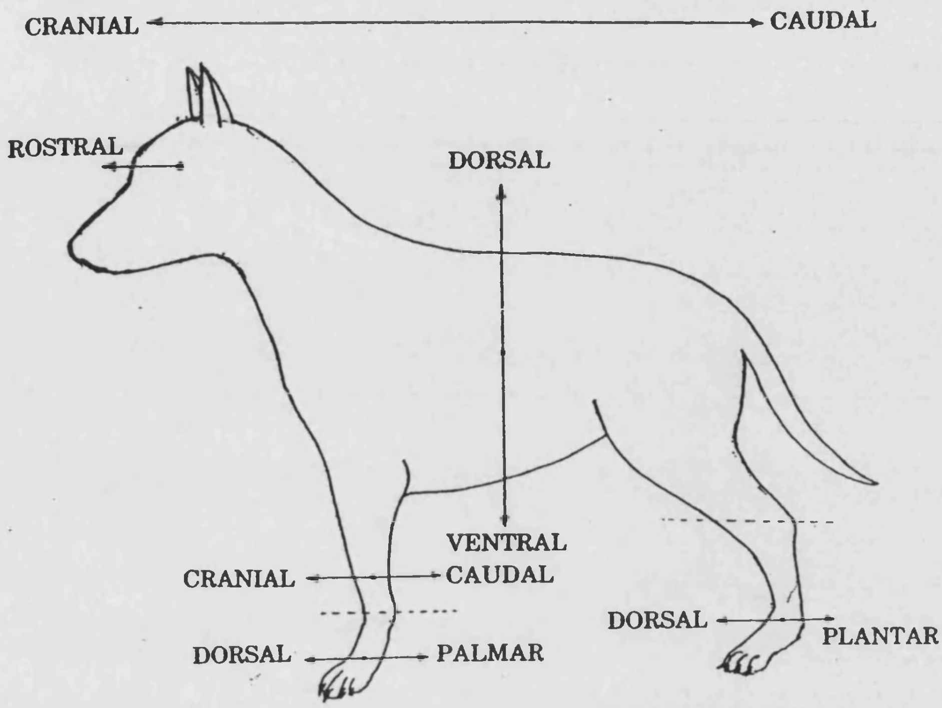


Figure 1-1. Lateral view of a dog to demonstrate anatomical directions.

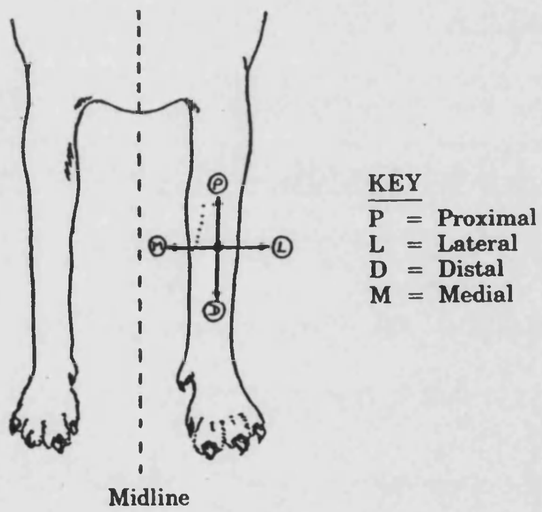


Figure 1-2. Cross-section of a dog at the level of the forelimb to demonstrate anatomical directions

Figs. 1-1 and 1-2: Diagrams to show veterinary anatomical directions. Reproduced from *An introduction to veterinary anatomy and physiology* by A. R. Michell and P.E. Watkins (1989), with permission of BSAVA.

NOTES

1 Professor David Gooding has suggested that this may be because we still identify 'knowledge' as that which can be articulated in serial, narrative form; the crux of my problem!

2 Independent of person, place, context or culture.

3 Thanks to Professor David Gooding for making this point.

CHAPTER 3: SEEING......

To gaze is to think....
(Salvador Dali)

3.1 Introduction

The arbitrary divide that I have put in place between the present chapter and the previous one (and for that matter, the next) is ostensibly for the purpose of 'convenience'. But whose convenience? Not my own in any real sense, since I feel that inherent in such a *textual* divide is the danger of intimating at an *actual* divide which (like Dali) I deny. Nor yet that of the reader, since s/he might be moved by it to mentally separate too rigidly the matters discussed here from those considered previously, or those still to be addressed. Perhaps therefore the term 'convenience' is better replaced by that of 'convention'; theses, and other lengthy works are *by convention* divided into discrete sections, or chapters.

A possible purpose for such division might be to enable easier organisation and understanding of the material. Perhaps after all we deal with complex issues better piecemeal, and some sort of categorisation is essential to cognition. This argument has been put forward by a body of work in psychology (eg see Brown 1956; Rosch 1977). On the other hand, the dangers of 'discreteism' - too rigidly adhering to the notion (or reality) of specified boundaries, have been stressed by Rayner (1997), in the context of the discipline of biology. According to Rayner, '*discreteness is an abstraction ... an unattainable ideal*' (p.3). He argued that boundaries can never be wholly fixed, but merely define what he termed 'dynamic contexts'. Thus it is at boundaries that life's action really takes place.

It is certainly at boundaries such as that between this chapter and the last (and for that matter, between this and the following chapter) that these tensions become acute. It was necessary both for the structure of this thesis, and also to reflect emerging distinctions which cut across existing, conventional ones, that I impose these (seemingly arbitrary) boundaries. The extent to which this imposition succeeds in promoting understanding is a matter for debate. It certainly does not seem to make either writing or reading about these topics *easy*; although perhaps in some special sense it renders it *possible*. Again I am unable to escape the narrative form. The only way in which I can justify actually making the division is by basing it roughly upon some or other vaguely relevant philosophical distinction.

Arthur Miller (1996) following Kant, Wittgenstein and Hansen, distinguished between the concepts of *seeing as* and *seeing that,* in which *seeing that* signifies seeing or understanding the deep structure of a phenomenon, whereas *seeing as* relates more to actual physical perception. These categories correspond roughly to the Kantian ones of *Anschaulichkeit* (visualizability) and *Anschauung* (visualization or intuition). To Kant, *Anschaulichkeit* is what can actually be seen (in the sense of being witnessed); the properties of an object that may be visualized in a physical way, for example in a drawing, a model or a simple experiment or demonstration, whereas *Anschauung* refers to abstractions made from such phenomena. Despite my mistrust of categorisation generally, (and my disquiet with crucial aspects of the Kantian critique which places intuition above sensation), I feel that this distinction may nevertheless be a useful one upon which to base this division of the mass of related (though not totally homogenous) material that will comprise this chapter and the next. I therefore address matters roughly corresponding to the concept of *Anschaulichkeit* (or 'seeing as') in this chapter, and *Anschauung* ('seeing that') in the next. It is important to point out however that these categories are by no means fixed, or mutually exclusive. There are undoubtedly alternative ways in which this material could have been categorised or organised, and also possible disagreements as to whether individual snippets should be placed *here* rather than *there.* Indeed, it is difficult in practice to consider one of these categories without relation to the other. I attempt to link the two by considering (mainly psychological) debates related to our uses of physical and mental imagery. In doing so, I doubtless provide further fuel for debates about classification!

3.2 Visualization of the body

Surgery, and for that matter medicine more generally, have understandable concerns with the visualization of the internal body; visualising here in the *Anschaulichkeit* sense of 'making visible'. Hirschauer (1991) described the difficulties faced by surgeons in 'creating anatomical visibility' in terms of a relationship that exists between experience and representation. He posed the question: 'How do patients' bodies come to embody the properties of anatomical pictures'? In chapter 2, ideas related to concepts of knowledge and 'experience' were discussed at some length. We need now to consider carefully those pertaining to 'representation'.

The technologies enabling (or facilitating) visual representations of the body have a long history which can be traced from the earliest anatomical illustrations, through three dimensional models such as those produced by Fontana in eighteenth century Florence; and from a different angle, the development of technological and / or optical devices which allow us to go beyond that which the unaided eye can perceive, allowing, in effect, 'extra-sensory perceptions'. Crucially, *all* of these media in some or other form are still used in both human and animal medicine and surgery, and are of particular importance in the education and training of surgeons and medics. It is true to say also that this is a history that is still being written, for example with the continuing development of 3D body imaging techniques, and questions relating to their interpretation and incorporation into medical and other discourses (Beaulieu 2000).

The literature deriving from art history, the history of science and medicine, and also science studies more generally, has much to offer in considering these matters in the light of my research topic. Miller (1996) pointed to the fact that representing something involves *re-presenting* it as either text or visual image, or a combination of the two. Why however, is it necessary to do this? It is argued that there may be a number of reasons why we do so. A 'visual image' may be simply a picture, a three dimensional model, a computer graphic, or alternatively some trace of the type termed an 'inscription' (eg, see Lynch (1985; Latour 1986, 1990), which is not necessarily 'representative' of the phenomenon in question in a literal sense.

For Lynch and Latour, 'inscriptions' were the results of *'writing and imaging craftsmanship'* (Latour 1986 p.4), and had a key function in the sciences as simplification procedures to render objects in the world 'docile' (Lynch 1985); less confusing and easier (literally, in some cases), to grasp or to see. Latour and Woolgar (1979) described how many aspects of laboratory practice could be made sense of in terms of processes such as that of 'transforming rats and chemicals' into marks on paper. Once simplified thus, such inscriptions lend themselves to novel processes of recombination and superimposition, which may in their turn lead to new representations, and new phenomena. Amann and Knorr-Cetina (1988) stressed also the *persuasive* function of inscriptions in transforming raw scientific 'data' into accepted scientific 'evidence'. This rhetorical role centres upon social processes of collaboration and consensus-forming within scientific communities.

Work by Larkin and Simon (1987) relating to diagrams, and also by Nersessian and Greeno (1990), and Roschelle and Greeno (1987) on the uses of abstracted models in physics showed how clustering interconnected information can render visual (and visible) a chain of interconnected inferences. They described how images may be stabilized for the viewer by the use of such models, and also how they can make various alternative versions of phenomena available for direct comparison in a way not possible for internal, mental images due to constraints of memory capacity.

Kearsey and Turner (1999) described how illustrations can facilitate the exposition of important scientific concepts through a form of graphic or pictorial scientific language. Goldsmith (1984), and Kress and van Leeuwen (1990) showed further how it is necessary to develop 'visual literacy' in order to become able to 'read' these pictures, in a similar sort of way to that in which we learn to read text. These points will be explored further in Chapter 4. One of the central concerns of this present work is to address the issue of the different roles that representations may perform within the research contexts.

I continue by reviewing in turn relevant (mainly historical) sources relating to anatomical illustration, 3D modelling and the technical and optical devices which enable extra-sensory perception; allowing us in effect to 'see' things which were previously invisible.

3.3 The uses of anatomical illustration

Anatomy: '*An opening up in order to see deeper or hidden parts.*'
Galen (130-200 AD).

Veterinary surgeon respondents were frequently observed to refer to anatomical atlases (eg see Boyd *et al* 1991), which comprise high quality photographic plates of the internal and external anatomy of animals, with explanatory keys. They also consulted surgical manuals, which are typically made up of line diagrams alongside detailed instructional text. Those concerned with orthopaedic surgery also tended to contain in addition photographs or reproductions of radiographs. Such publications take on particular importance in circumstances where the operating surgeon is either in training, or qualified but still relatively inexperienced, and also when an unfamiliar procedure is being carried out, or when the patient itself is of an unfamiliar species.

These textbooks are very similar in design and content to those used by physicians and surgeons in human medicine. This is unsurprising given that the history of veterinary anatomical illustration is closely tied up with that of its human counterpart. One reason for this is that historically, the cadavers of animals were frequently substituted for human corpses for dissection purposes in medical universities. This occurred for a number of reasons, such as the lack of availability of sufficient human corpses, and social stigmatization and religious disapproval of the practice (Turner 1990). Many of the 'mistakes' of the early anatomists could be put down to their being unaware that human anatomy is not identical in every respect to that of the animals they dissected. To give an example, many of Vesalius' drawings show the liver as a lobed organ, as indeed it is in cattle and deer; the human liver however is unlobed.

The history of anatomical illustration is well documented elsewhere, (eg, Roberts and Tomlinson 1992; Cazort *et al* 1996; Persaud 1997*)*, but briefly, *scientific* anatomy began in ancient Greece before the time of Christ, and was continued and developed further in the second century AD by the Greek physician Galen. Little European material survives prior to the advent of printing in the sixteenth century. Probably the most famous anatomists of this period were Leonardo da Vinci and Andreas Vesalius. Leonardo's drawings (although familiar now) remained unpublished during his lifetime. Those of Vesalius however were used as teaching aids, alongside accompanying texts (a similar pattern to that of modern surgical manuals). Vesalius and others also produced interactive 'flap anatomies'. These were woodcut prints representing the outline of the body, upon which smaller illustrations of separate bodily organs could be superimposed. This was suggestive of the three dimensional, layered nature of anatomy itself. These flap anatomies had detailed instructions for assembly, and it can be surmised that this handling of the material rendered it of considerably more learning value to novice surgeons than pictures intended merely to be looked at.

Stubbs' *Anatomy of the Horse* (published 1766) provided an early example of a veterinary anatomy. A number of comparative anatomies (i.e., comparing human anatomy with that of various animals) were also published at around this time, notably by Felix Vicq d'Azyr (1748-1794). Vicq was a particularly important figure in the history of anatomy because he was one of the first anatomists to treat the body's organs as geometrically solid shapes, to be analysed in a systematic way. First he would examine the exterior planes, angles and edges of the organ, and then those of its interior. Camper (1722-1789) also 'built bodies' according to geometrical methods, using series of precise measurements (Stafford 1994). Anatomists at this time were already beginning to distance themselves from the world of 'art', adopting an approach that could be seen as more 'scientific', in their use of such 'objective' criteria as measurements. However, how far this stands up as a valid distinction between 'art' and 'science' *per se* is open to debate, dependent as it is upon a point of view that sees measurement firstly as peculiar to the sciences, and therefore outside of the province of artists, and secondly in some way more 'objective' than other human observational activities. We will later see that this approach is not without its own problems and inconsistencies!

Roberts & Tomlinson (1992) described how photographic atlases (as opposed to those based upon drawings) were first produced about a hundred years ago. These would at first seem to have obvious advantages over art work, in their apparent 'realism'. However, dead corpses are not identical to living bodies, either in photographs or indeed in 'the flesh'. Processes of decay, the use of preservatives, and the act of dissecting itself, can and does affect their appearance, and all of this can prove misleading and limit the usefulness of such photographs as aids at the operating table. Information obtained during surgical operations, from radiographs, scanning technology and endoscopy are therefore used to supplement images derived from the dissected corpse, in the same sort of way to that in which da Vinci would combine information from many dissections into one single illustration. Even here, images are accumulated, or superimposed to better enable visualisation.

It is I feel misguided to imagine that a photograph is necessarily less subjective (or conversely, more objective), than a drawing or an engraving, particularly in this context. Such a photograph (like all 'scientific' images) must in fact be carefully composed (or constructed), to be of any practical use at all, and in some senses and situations 'subjective' art work can be of equal, or greater practical value than seemingly more 'objective' photography. The camera, in essence, can (and frequently does) lie!

Roberts and Tomlinson (1992) distinguished between the roles of 'diagrams' and 'images' (pp.7-9) for anatomical illustration. In an anatomical *image* such as a photograph in an atlas, (however well constructed) the complicated structures of the internal body appear muddled, and it is very difficult to distinguish the individual parts. This is the case even where (to give an example I have used myself in conference presentations), entire systems have been removed to enable others to be seen more clearly (Boyd 1991, p.218). In this example, the entire gastro-intestinal tract has been removed to render more visible the reproductive organs of the female canid.

Moreover, images are less easily memorised than diagrams, because of their complexity. *Diagrams* on the other hand, are abstractions (or further abstracted, if like me you consider that photographic images too are abstractions from objects in the world). They are not intended to 'look like' the real thing, but are useful nevertheless in conveying certain properties relating to shape and relative position, and to help relate structure to function. They are thus more generalisable than images, and therefore more able to accommodate individual differences. They do not however, (and neither are they intended to) convey the actual appearance of the organs and structures in the dissecting room or at the operating table. Kearsey and Turner (1999) described how line drawings can act as a prompt in scientific communication to enable the viewer to create for him or herself the image depicted (p.87). This is an interesting idea in relation to the way in which one of my respondents explicitly spoke of combining physical and mental imagery (see chapter 7). However, following Lynch and Woolgar (1990), who described how scientists juxtapose different forms of (physical) representations for different purposes, I will later show also how, rather than any one representational form necessarily being used in preference to another, they may be used *together*, each enhancing the other by combining information.

3.4 Displaying the third dimension....

'The visual system creates the three-dimensional world we experience from the two-dimensional patterns projected onto the retinas - a feat that, odd as it may seem, is a bit like imagining a building from its blueprints...'
Richard Mark Friedhoff and William Benzon, 1991.

I borrow this sub-title from that of a conference held in London at the Wellcome Institute and the Science Museum during Autumn 1998, which was of obvious interest to the present work[1], and the accompanying quote from a publication whose interest lies at the other end of the temporal scale, but whose subject matter is arguably in many ways similar. Its concern is with recent innovations in computer imaging, whereas the subject of the conference was the uses of 3D models in the history of the sciences, technology and medicine. The proceedings are as yet unpublished, but I refer extensively to conference presenters and their papers, in the hope and expectation that these will soon become generally available.

Many of the papers addressed this problem of the necessity to move between dimensions when visualizing real-world phenomena, which is essentially one of my central concerns. In the previous section I briefly discussed the history, uses and drawbacks of anatomical illustrations for visualizing the body. Alongside these two dimensional illustrations, 3D models were (and are) also used, and for similar purposes. I feel that it is important to stress that the boundaries between the two- and the three-dimensional are by no means as clear cut as would at first appear. Rooke (1994) for example suggested that all visual representations can be thought about as three dimensional, in that they involve a social dimension, a physical dimension and the brain. She argued that we experience a multi-dimensional interpretation due to our 'seeing' an overlap between them.

I wish to introduce (or reintroduce) at this point the notion of *superimposition* (Latour 1986). As we have already seen, two-dimensional images of diverse origins can be (and often are) superimposed one upon another in complex ways, and I would assert that this can effectively blur, or breach such boundaries. The flap anatomies mentioned earlier, in which small pictures of various organs were superimposed upon a larger one representing 'the body' to give some idea of the three dimensional, layered nature of anatomy, provide an early (though ingenious) example of this. Modern examples are produced by the techniques of CT and MRI scanning technologies, which can superimpose one upon the other images of adjacent 'slices' of the body, thus building up a three dimensional representation of the body's interior. Todd-Pokropek (1998), in a review of the journal *Medical Image Analysis* stressed the publication's concern with the production of 3D displays by combining, displaying and interpreting data from different imaging modalities. I will later show how my own respondents superimposed and combined 2D images from a variety of sources in a much more *ad hoc* way, in order to better understand, construct, convince and communicate.

Tufte (1990) discussed precisely this problem of communicating information about a complex, three dimensional world in the confines of the two dimensional space of paper, or 'flatland' as he and others (e.g., Abbott 1884; Stella 1986) have termed it. Tufte shows examples of some of the ingenious ways in which this problem has been overcome, and also discusses some attempts which have failed, sometimes spectacularly. Alpers (1983) described how the Dutch *descriptive* painters of the seventeenth century shared similar concerns, and how they overcame the problem to some extent by treating the canvas as an 'externalised retina' to be painted upon directly, rather than as a window or stage looking out upon the world as the classical Italian narrative painters had tended to treat it. This metaphor was re-employed by Lynch (1985), when describing practices by which natural objects are rendered visible and analyzable in scientific research.

As has already been intimated, the complex, layered nature of anatomy is an area which has historically posed particular problems of dimensionality. Anatomical pictures, however accurate, are generally in two dimensions, and anatomical reality in three. From my own experiences of learning and also teaching anatomy, I would argue that this problem of dimensionality has by no means been overcome. This brings us to further consideration of 3D representations, or 'models'. Baker (forthcoming) described the problems and ambiguities inherent in defining the term 'model', and also its shifting, mobile nature. A model may be used as a representation of a larger work (such as a sculpture, a monument or a building), as an explanatory device, a means of persuasion, or as part of a production process, (as in ceramics). They can be used also as a means of communication, perhaps to complement verbal accounts, and in turn be complemented themselves by drawings (which might be 'models for the model').

My own students have found the use of three dimensional models of individual organs such as the heart and the brain useful; more useful in fact than the real thing, since they are more solid, and can be dissembled and put back together again, (which is more than can be said for ex-abbatoir organs inexpertly dissected). They found them more useful in some ways also than pictures, which are unable to convey much sense of the size and depth of an organ, or the actual positions in 3D space of the parts and layers which it comprises. Actual or model skeletons are useful in the same sort of way, for demonstrating the positions of the bones relative to one another, and the ways in which they articulate. However, despite their seeming advantages, I will later show that the use of 3D models *can* be problematic in some circumstances, in ways that are complex and difficult to understand, and that in fact 'layers' of superimposed pictures can on occasion be more effective.

Latour (1986) has shown in the context of studies of both scientific practices and also more 'applied' endeavours such as engineering (which like me he considers are often inappropriately and unduly separated from science), how a paper world can be manipulated (despite its seeming limitations) *as if in three dimensions,* by means of such juxtapositions of inscriptions. As Latour (ibid p.22) put it, *'the two-dimensional character of inscriptions allows them to merge with geometry... space on paper can be made continuous with three-dimensional space'*. A result of this is that *'we can work on paper... but still manipulate three-dimensional objects 'out there'.*

The world of the computer screen is also in a sense a two-dimensional 'flatland', which shares many similarities with that of paper. However, it provides means of creating, modifying, combining and superimposing images, and parts of images, that seem not to be dependent upon the limitations of physical manipulation and working memory that constrain us when we work with paper (Friedhoff and Benzon 1991), but provide previously undreamt-of opportunities to visualize more *actively.* This was demonstrated very emphatically in relation to an example from very modern (even experimental) surgery recently encountered at a conference[2]. Professor R. Kitney of St Mary's Hospital and Imperial College, London described advanced technologies whereby images from MRI and micro-endoscopy can be used in combination. Eventually for example, the position of a micro-endoscope within the spinal column could be tracked by MRI, so allowing surgeons to see previously invisible details of anatomy and context. These interventional MRI technologies (iMRI) are still in the developmental stages at the time of writing. Imperial College / St Mary's Hospital presently has the only equipment of this nature in the UK.

This problem of dimensionality in anatomy, far from being new, is one which has been readdressed at various times throughout the history of surgical and medical education. The wax models commissioned by Felice Fontana, not only of the human body, but also of plants, animals and pathological conditions, are a case in point. These were intended as teaching aids, and supplemented by drawings and texts. Many were made larger than life size to better show the complexities of for example, the blood and lymph circulatory systems. These models were extremely detailed, and were themselves constructed from juxtapositions of images, from pictures in anatomical atlases and also directly from dissections, sometimes multiple dissections. The models were not handleable due to their delicate construction. Less detailed, and certainly less aesthetic, but according to Fontana himself, far more useful for didactic purposes, were other, wooden models which could be taken apart and reassembled by students. Fontana stressed the fact that it was the 'putting together' of these models which gained most knowledge. This shift from wax (which could not be handled) to wooden (handleable) models, even though these were less detailed, was significant, because the latter entailed the **use of both eyes and hands** so salient to surgery (Mazzolini, forthcoming).

Hopwood (1999) also described this idea of 'building a 3D model with the hands in order to visualise it in the head', this time in the context of nineteenth century embryology. Microtomes were used to render structures in very thin slices, and embryologists subsequently made sectional wax images of these, which could then be used to reconstruct the whole. Hopwood (ibid p. 466) described this as a '*complex interplay between two and three dimensions*'. These larger-than-life 'wax plate reconstructions' became a primary means of visualising embryos, which are often so small in life as to be almost invisible to the naked eye. These models were actually *published* to accompany textbooks and research papers, another example of the superimposition of complementary representations to aid understanding. Further than this, Hopwood stressed how embryologist and anatomist

Wilhelm His constructed these intricate wax models alongside other, simpler 'mechanical' models in rubber or leather (which were intended to mimic the processes by which the embryos developed, rather than to emulate their form). These ostensibly separate kinds of model were (as Hopwood put it) for him merely two modes by which he modeled. In the same laboratory, His colluded also in the construction of *mathematical* models.

Newman (1996) and Petherbridge (forthcoming) were concerned with the movement between dimensions entailed in the use of obstetrical illustrations and models intended as training aids for obstetricians and midwives. Again, both wax and wooden models were produced, and these were used in conjunction with both 2D illustrations and texts. Petherbridge described the dynamic nature of this particular use of models as a sketch, a means of moving towards something; terming them '*obstetrical machines that talk to the eye*'. This use of other sensory modalities alongside vision in '*making sense of the world*' (literally, in some respects) and gaining knowledge, is a theme that recurs frequently. These examples stress the importance of the use of the hands (touch sense) and eyes together in learning about things in the world. Elsewhere I have also discussed kinaesthetic sense, our sense of the orientation and movement of our bodies.

In a similar way to that shown by these historical examples, modern-day surgeons also have understandable concerns with touch-sense. Several of my research respondents alluded to this, describing for example the importance of the 'feel' or texture of different bodily tissues, and the 'tension' on certain ligaments. Professor Ara Darzi of Imperial College and St Mary's Hospital, London, spoke about laparascopic techniques (keyhole surgery) in which surgeons' *'eyes are miniaturised and ... hands extended to enable operations to be performed through a tiny incision in places which could only be reached formerly via a large incision'*.[3] According to Professor Darzi, such techniques *'effectively exteriorise the internal body so that it can be seen on a monitor screen'*.

He drew attention also to safety issues in relation to this, which are connected with the use of unfamiliar skills and instruments, but also with a lack of tactile feedback, and the fact that the 2D images on the screen take away the stereo-cue from the surgeon. This is especially interesting, since I have observed surgeons experiencing problems in reconciling 2D images with the

3D reality presented on the operating table. It would seem though that, if the 3D is 'taken away' altogether from the surgeon's point of view, even more problems may potentially arise. Although the 'switching between dimensions' that I have observed is difficult, it is apparently less so than trying to do without, or ignore the third dimension entirely. Future robotic technologies are planned which will 'give back' some of this sensory input to surgeons, via tactile feedback for example.

Recent work by psychologists Susan J. Lederman of Queens University Ontario, and Roberta Klatzky of Carnegie Mellon University (1998) has attempted to address questions about how we perceive touch. They have discovered six basic exploratory procedures that people use to learn about objects with their hands:

- rubbing the fingers across a surface to provide information about an object's texture
- pressing down on an object provides information about its hardness
- static contact - holding the fingers in one spot provides information about an object's temperature
- holding an object out away from a support provides information about its weight
- wrapping the hand around an object provides information about its global shape and volume
- moving the fingers about the perimeter of an object provides information about its exact shape

According to Lederman and Klatzky, these procedures are performed in a logical pattern, and in order to design robots that can use tactile sensors to analyse an environment, it will be necessary to devise sequences of systematic manual testing procedures that will extract the appropriate tactile information. Research indicates that touch sense is extremely sensitive to material properties such as those described above, but relatively poor at determining spatial and geometric properties such as whether an edge is sloped to the right or the left, or whether it is horizontal or vertical. This type of information is are far more effectively gained via the visual system (Azar 1998). It is research of this kind which may provide insights into how best to construct the surgical robots of the future, and indeed others which can be used to perform intricate tasks in 'remote' environments.

To reiterate, the problems discussed here are not new, but can be traced through the past, present and future of medicine and indeed science more generally, not only via the use of robotic technology and 3D models but via the history of optical technologies. I digress somewhat. It will be a considerable time before some of the new techniques described here will become available to *veterinary* surgeons like my research respondents. Nevertheless, I feel that this approach is relevant to, and supportive of, my own. I return to consideration of vision.

3.5 Extra-sensory perceptions

'Material objects that till now were classified among atoms, since they far elude all human eyesight, presented themselves so clearly to the observer's eye that when even completely inexperienced people look at things which they have never seen, they complain at first that they see nothing, but soon they cry out that they perceive marvellous objects with their eyes. For in fact this concerns a new theatre of nature, another world.....'
Warp, J.A. (1897). Cited in Alpers 1983.

Warp wrote thus about microscopy, and this quote (whilst it conveys the excitement inherent in the use of an optical device which allows us to perceive things that are invisible to the naked eye), skates too readily I feel over the difficulties likely to be encountered by the inexperienced in interpreting their observations. My disquiet with this idea stems from my experiences of teaching biology (particularly *micro*biology). It is true that there does indeed come a day for most people (if they persevere for long enough) when they can perceive for themselves 'marvellous objects' of the type referred to, but such skills take a long time to acquire, are hard to grasp and even harder to understand. Moreover, the acquisition process itself seems to be social in nature.

Dennis (1989) described the extraordinary lengths that Robert Hooke had to go to in the seventeenth century in order to enable other people to use his new microscopes. The instruments themselves were not standardised at that time, since no two lenses were likely to be ground exactly alike. There was not the technology available. His problem was therefore to move observations made via this non-standardised instrumentation from the realm of private experience (his own) to the status of public, and therefore verifiable knowledge. He accomplished this by means of his book *Micrographia* (1665), which contained detailed instructions for the 'disciplined seeing' (Dennis 1989 p.323) of various specimens; a form of standardisation of the *viewing method,* to compensate for the non-standardised nature of the *equipment.* Briefly, this method involved multiple viewings under various (specified) lighting conditions in an attempt to discover the 'true' appearance of his specimens. *Micrographia* contained likenesses of this purported 'true' appearance of various specimens alongside the instructions that enabled their viewing using the microscope.

One of *Micrographia*'s central themes was the employment of instruments to enlarge the scope of man's (sic) imperfect vision (Dennis 1989 p.318). It provided in addition (and probably more importantly) the *standard* by which a community of microscope users could be built up. It was intended not as a *book* to be simply read, but as a *tool* to be used in conjunction with the microscope itself. Though Hooke's drawings were inevitably interpretations (or representations) of what he himself had seen, he considered on the contrary that he had reproduced 'objective' representations of his specimens. This led to disputes with engravers who worked on *Micrographia* whom (Hooke considered) did not exactly reproduce his drawings as he had intended. It was essential that the prospective microscope user learned to 'see' in the manner described by Hooke (and therefore, inevitably, that he 'saw' the same likenesses), otherwise he would merely *'wander in the labyrinth of groundless opinions'* (Dennis 1989 p.330), as opposed to seeing what was 'really' there.

The social nature of microscope use, this need from the inception to build a 'community' of microscope users, can be easily surmised in classroom observations of students learning microscopy. Students seem to become able to 'see' objects by social means, by talking about, and comparing what they see, with each other, with their teachers and also with pictures or projected images of a similar specimen. In essence, modern microscopy students use similar methods to those used by the readers of *Micrographia*; our instruments are now uniform and standardised in nature, but our students still seem to need to learn to use them by means of standardised (and consensual) methods.

If the microscope was effective in extending the power of the eye through magnification, other technologies could be said to further extend it by means of enabling one to see through opaque surfaces, such as the surfaces of the body. During the late nineteenth and early twentieth centuries, the development of radiography and endoscopy made it possible for the first time to look inside the body without first cutting it open. Such technologies brought with them however similar problems and debates relating to their use, and particularly to the interpretation of the images produced.

Bernike Pasveer's (1993) paper was interesting in that it criticised 'traditional' histories of radiology (eg Brecher & Brecher 1969) for their assumption that the content of x-ray images is essentially unproblematic, given the 'fact' that the pictures would naturally relate to 'what was there', and that it was necessary only to learn how to read, or 'decode' the pictures in order to decipher their implicit meanings. Pasveer argued on the contrary that it was necessary for the pictures to have been 'coded' in the first place, by specific 'rendering practices' (in which the pioneers of medical radiology set out to construct the 'true' content of the pictures, in much the same way as Hooke had done for microscopy by means of *Micrographia*), prior to any such 'decoding' being possible.

One way in which the 'coding' of radiographs was accomplished was by *'creating likenesses between the shadows produced and other modes of representing, and between shadows alone'* (Pasveer 1993). Radiographic pictures of, for example, the chest, would be compared with the sounds it produced on percussion, and with radiographic pictures of other chests. For Pasveer, the content of visual representations is 'made' by such methods, rather than 'discovered'. Decoding becomes possible only as a result of the emerging representational practice; the two, the coding and the possibility of decoding the images, develop together in order to enable their visibility.

Vasseleu (1991) continued this theme of the construction of medical imagery in relation to endoscopy, which collective name covers a range of techniques which enable the visualisation for diagnostic purposes of internal body cavities by means of a tiny video camera attached to a flexible tube. Rooke (1994) similarly described how modern day CT images are constructed by means of corroboration between expert practitioners, the surgeon and the radiologist; the radiologist adjusts the contrasts on the scan in line with the initial hunches of the surgeon (p. 33); essentially Hirschauer's (1991) relation of 'experience' and 'representation'.

Since then, ultrasound, and more recently, the still-developing technologies of magnetic resonance imaging (MRI), computer-aided tomography (CT scanning) and positron-emission tomography (PET), have provided still further opportunities for visualising the body, the latter three with the important difference that they can provide 3D, rather than 2D imaging. While MRI and CT technologies image the structure of the body, PET scanning visualises biological functioning in a related sort of way to the graphical techniques referred to below. Crary (1990, p.1) argued that modern techniques such as these are relocating vision to a plane separated from the actual human observer, and that this causes most of the functions of the human eye to be supplanted by practices in which visual images no longer have reference to an observer in a 'real' optically perceived world. However, I feel that this point of view depends upon a particular (and contentious) notion of 'seeing'; similar in fact to that displayed by Hooke in his disagreements with his engravers. Such an explanation takes too literally the idea of the 'reality' and 'objectivity' of our perceptions, and fails to address the notion that all of the things that we perceive can in fact themselves be construed as 'representations' of things in the world. Gombrich (1959) stressed the extent to which our knowledge and expectations influence our perceptions: '*All perceiving relates to expectations and therefore to comparisons*' (p.254). Our own particular slant upon 'reality' is therefore likely to depend heavily upon the social, cultural and intellectual milieu within which we are situated.

The use of these latter-mentioned imaging technologies is limited in veterinary medicine at the present time, to a very few specialist units (for example in connection with animals of great economic value, such as racehorses, and for research purposes at veterinary universities). They are not used in the type of local general practices in which my fieldwork was carried out, and so are outside the scope of the present empirical work. This is not to say, of course, that they are not of interest, and worthy of investigation in their own right in connection with the research questions posed here. For an interesting introductory overview setting these methods in the context of the history of body imaging, see Stafford (1992). For more contemporary accounts which give specific examples, see Rooke (1994), Friedhoff and

Benzon (1991), and Beaulieu (2000). Their emerging use in veterinary medicine is something that I would very much like to research myself in the future.

3.6 The graphical method

Alongside technologies which enhance and magnify *objects* enabling them to be seen and studied, there exist others which enable otherwise imperceptible *movements* to be perceived where this would be impossible were they not slowed down and recorded, or traced. Early examples included the kymograph, which could be adapted to record movements such as those of the heart during the cardiac cycle and other physiological events which had literally been 'invisible' prior to this. De Chadarevian (1993) referred to these technologies as 'bodily inscription devices' *which provide a 'solution for visualising and quantifying time intervals not perceptible to our senses*' (p.275). She described the debates that arose with regard to their accuracy, which were compounded when it was discovered that the same phenomenon (for example, the human pulse) when transcribed by different devices, would yield different traces.

This situation again, led to a need for standardisation of both the instruments themselves and of the methods by which the traces are interpreted. This was accomplished, by the establishment of common standards which '*disciplined experimental practice and normalised experience'* (de Chaderevian 1993 p.290). These technologies are collectively known as 'the graphical method' (after Marey 1878), and were the forerunners of modern devices such as the electrocardiograph.

Hatt (1995) researched the history and significance of the measurement of blood pressure. She described how this 'digitisation' of bodily events has been used to determine whether a body is 'normal' or 'abnormal'. This concept is in itself interesting, particularly since my observations have led me to conclude that digitisation does not produce *one* version of a 'normal' or 'abnormal' body, but measurements are considered 'normal' within a given range. This 'normal range' varies between animal species and even *within* species is sometimes quite wide, and also subject to some variation.[4]

Borrell (1986) wrote of the ways in which the tracings of early recording devices enabled the gradual evolution of a new conception of such bodily processes as interrelated, rather than separate events, and conversely, to allow the visual separation of simultaneous events via simultaneous registration. She described how such techniques became an important means of revealing the internal workings of the body and helping physicians to evaluate the course of a disease's progress, as well as detect its presence at an earlier stage than was previously possible. Again, Borrell's paper stressed the tensions and debates that existed (and exist still) with regard to the interpretation of the traces of these machines. Similarly, Hartland (1993) showed how the interpretation of electrocardiograph data remains problematic.

Still other devices are used to quantify *substances* within the body. Examples include haematology analysers which count the various (normal) fractions present in the blood, and biochemistry machines which measure, among other things, substances such as enzymes in blood serum or plasma which are *not* present under normal circumstances, or are present only in extremely small amounts, but whose level may be elevated as a consequence of certain pathological conditions. Such analyses can provide information relating to the functioning of various bodily organs such as the heart, liver and kidneys, and also assist in monitoring the course of a disease process. Some models also provide a list of potential diagnoses of problems that could be causing the occurrence of levels of these substances outside of their so-called 'normal range'. These lists appear to be of some, but limited value to veterinary practitioners. This is borne out by examples from the literature pertaining to the use of computerised diagnostic equipment in human medicine, (see for example Hartland 1993).

So much for consideration of the uses that 'physical' imagery may have to participants in my main research context. Of particular importance are firstly, the ways in which pictures and other 'inscriptions' that are of interest to research respondents are constructed, and the ways in which various types may be used, either alone or in combination with others. Secondly, the tensions implicit in the interface between two dimensional 'images' and three-dimensional 'models', and the observation that the division between what is 2D and what is 3D is by no means as clear cut as would at first appear. Thirdly, that many of the examples quoted have highlighted the importance of the use of the hands alongside that of the eyes. Fourthly, that the interpretation of images produced by 'new' technologies is not a simple matter, but successive historical and present-day examples have shown them to be dependent upon both specific 'rendering' or 'coding' processes and social consensus.

I now move on to consider 'mental' imagery. I begin by briefly discussing debates as to whether or not it actually exists (or as I interpret the situation, debates as to the nature of the underlying processes and mechanisms responsible for the imagery we experience).

3.7 The great mental imagery debate ....

Mental imagery is a contentious subject for a variety of reasons. Like 'knowledge' considered previously, we find it difficult to define precisely. Paivio (1991) reviewed some of the various definitions that have been put forward, in the realms of literature and psychology and also in more general parlance. 'Imagery' can refer to descriptive language and figures of speech, or 'picture words' (Paivio 1991), as used in poetry and other creative writing forms. It can also be used to describe the 'mental pictures' that we experience when imagining the appearance of familiar objects, places and people. Paivio also described how imagery can be used unconsciously. It is not necessary for example, for mental visual images to be actively 'in the mind's eye' all of the time, since they can be invoked as and when required (p.252).

Paivio (1991 p.252) divided these various definitions or uses of imagery into two general categories; imagery as *expression* and imagery as *process*. In the first category, the expression can be either overt (as in art, literature and science), or covert (as in internal, mental images). In the second, the term *process* refers to the mental representations and mechanisms that are involved in the production of expressed images (of either type). No-one denies that we experience mental visual imagery in the *expressive* sense; the debates revolve rather around imagery as *process*. Imagery in this sense lies largely outside the remit of this thesis. Neither my methodology nor my experience are appropriate for the investigation of this phenomenon, particularly since it has now largely moved into the realms of neuroscience. I think it interesting and useful however to briefly consider some of the main arguments that relate to it.

The main thrust of the debate appears to lie in the way(s) in which information is thought to be coded[5], stored in memory and processed. Steve Kosslyn and his various co-workers have argued that an analogue processing mechanism (or mechanisms) for dealing with imagery exists alongside a propositional one which deals with linguistic input (see for example Kosslyn 1973; 1980; 1987; 1994; Jolicoeur and Kosslyn 1985; Kosslyn and Jolicoeur 1980; Kosslyn et al 1978; 1984; 1985; 1990; 1993; 1995). Kosslyn's view is supported by the work of Shepard (1975; 1978) and his associates (Shepard and Cooper 1982; Shepard and Feng 1972; Shepard and Metzler 1971), which shows how 'mental' objects can be rotated and otherwise transformed in much the same way as 'physical' ones. Also, Paivio's (1991) 'dual coding theory' of information processing, which proposed that cognition is served by two experientially derived and modality specific symbolic systems, one of which is specialised for language and one for imagery. Paivio stressed however that although they can work independently, these codes are not totally separate, in that information encoded in one modality can easily be transformed to the other, and where necessary they can both be used together and simultaneously.

Various evidence from neuropsychology, including the use of PET scanning technology, and studies of subjects whose visual cortex has been disrupted due to brain damage, has also been put forward to support the imagist (or analogue) thesis (eg, Farah 1988; Farah *et al* 1992; Kosslyn 1994). This has shown that some visual areas of the brain are topographically organised in the same way as the retina of the eye, and also that mental imagery uses some of the same neural representational mechanisms as vision. Countering this argument, others have been proposed, notably by Pylyshyn (1973; 1978; 1979a; 1979, and Anderson (1978; see also Anderson and Bower 1973), which deny the existence of any such analogue mechanism (although they do not deny our *experiences* of imagery). According to these theories, only a propositional mechanism exists. Imagery as we experience it is thus epiphenomenal, and largely a consequence of our goals, beliefs and tacit knowledge. It has been proposed that during the course of many of the psychological experiments carried out by members of the 'imagist' lobby, subjects were actually simulating witnessing real events taking place, and their tacit knowledge of the imaged situation caused the reported transformations to take place along the lines that they would in reality.

These arguments are fascinating. However, as previously stated, they deal with subjects largely beyond the remit of the present work, and I concentrate rather upon (visual) imagery as *expression.* I move on to consider what such imagery (as we experience it) is actually *like*, and how we use it, (or rather how people may use it in the present research contexts).

3.8 Imagery as *expression* (Paivio 1991): What is it like?

Imagery: 'Seeing' in the absence of the appropriate sensory input, a 'perception' of remembered input rather than new information.
Steve Kosslyn (1995 p.267)

Somewhat simplistically, mental visual images have been compared to 'pictures in the head'. Such explanations imply however the necessity for a 'little man inside the head' (or 'homunculus' - I remain uncertain as to why it is necessary for such an entity to be gendered) - to look at them. This in turn implies a necessity for other little men, and so on *ad infinitum*, a situation leading to infinite regress. More sophisticated explanations avoid the need for small beings of either gender. According to Kosslyn (1980) for example, images are actively constructed, dynamic, 3D, 'quasi-pictorial' displays which are not necessarily 'photographically' accurate. They may be scanned in a similar sort of way to 'physical images' of the type discussed earlier in this chapter. They can be maintained (with some difficulty; Kosslyn (ibid p.280) described them as 'fleeting' and 'ethereal', Pinker (1998, p. 294) as 'fragmentary'). They can also be transformed in various ways - think of visualizing for example the rearrangement of furniture in your room before you physically do the rearranging. We often try things out in this way prior to actually acting. Speaking as a biologist, it saves energy! (This is incidentally not a 'funny' remark; imagery may have had very real evolutionary benefits in some such respect). They are also flexible in ways not possible with words alone. Linguistic material is necessarily sequential; this is one of the core problems with which I am trying to deal. Images though are synchronously organised, like a fabric, and so free from such linear or sequential constraints (Paivio 1991 p. 266-267).

Though flexible, they are also specific; try as you might, it is impossible to visualise a bird, or a triangle for example, in general (Pinker 1997). A specific (often prototypical) bird, triangle, or other object has to be imaged.

At the same time however, these 'specific' objects can somehow substitute for others in a 'general' sort of way. Paivio (1991 p. 255) described visual mental images as 'visual metaphors'. I will return to consideration of this idea later. Though not the main focus of this study, these psychological theories about how cognitive construction takes place deserve consideration in respect of their potential contribution to any broader theory of how people construct useful imagistic representations, and how these interface with their 'physical' counterparts.[6]

3.9 And how we use it.....

The process of 'looking' at imaged objects seems to share many of the properties of actual perception (Kosslyn 1995). Pinker (1998) described our use of imagery as a means of answering certain types of questions pertaining to familiar (or relatively familiar) objects. To address the question 'What shape are a beagle's ears?' for example, we visualize a beagle, which feels like conjuring up a picture available for inspection in the mind's eye. Pinker differentiated between such 'concrete' questions and the more 'abstract' type (he gave the examples of *'What is your mother's maiden name?'* and *'What is more important, civil liberties, or a lower rate of crime?'*) best addressed by linguistic means (p.284). Such differentiations however need to be considered in the light of difficulties relating to 'concrete' and 'abstract' phenomena already discussed.

According to Paivio (1991) we use imagery in certain, distinct ways:

- As a mnemonic device; 'concrete' objects are more easily remembered as visual images than by means of words (see Paivio 1971; Richardson 1980). Generating mental visual images in response to material to be learned can assist with retention (Paivio 1971).

- In certain types of creative thinking (eg in art, or science). This is discussed much more fully in the following chapter.

- In conjunction with language. I return to this theme in Chapter 5.

Kosslyn (1995 p.268) described how imagery can be used to identify objects, their parts and characteristics, particularly when the information to be remembered is of a subtle nature, or where the property has not been explicitly considered before, or cannot easily be deduced from other stored information. In his analysis, a second role for imagery is in that it parallels the role of vision in allowing us to navigate, track and reach for objects; imagery is thus a means of anticipating what will happen when one's own body or a physical object moves in a particular way. Kaufmann (1990) argued that imagery is especially valuable in what he called 'ill-structured task environments' (p.173), which are characterised by a lack of experience of the task in hand, or in the case of especially complex problems (such as those likely to be faced at times by my research collaborators), and that it becomes less important in more familiar task situations.

It is interesting to speculate about how and when 'mental' visual imagery is used in conjunction with the 'physical' kind, and to consider related topics such as when it is sufficient alone, and how we cope in situations where we are unable to form a satisfactory mental image because we have too little experience of the object or situation in question. It is to be hoped that my data will contribute some small insights into these questions. It is now time however to carry the discussion forward to reflect upon 'seeing' in the *Anschauung* ('seeing that') sense.

NOTES

1 Conference entitled '*Models in the Sciences, Technology and Medicine*', 13-14 November 1998, at the Wellcome Institute and the Science Museum, London, UK.

2 '*Visualisation in Surgery*', Saturday 9 September 2000, at Imperial College, London, UK. Part of the BA Festival of Science.

3 Ibid (note 2).

4 See chapter 9 for further discussion of this point.

5 Professor David Gooding pointed out that this meaning of 'coding' is different from that used previously. Here, it represents a hypothesis about how the brain works; in sociological studies (such as that of Pasveer 1994), social or cultural 'encoding practices' are the focus.

6 I am indebted to Professor David Gooding for raising this point.

CHAPTER 4: 'KNOWING AND SEEING'

'The real act of discovery consists not in finding new lands, but in seeing with new eyes...'
Marcel Proust

4.1 Introduction

In this chapter, I consider a number of related matters that are also related (as usual) to those previously discussed. Again, my attempts at communicating complexity are constrained by narrative, principally because many of the complex relations and connections that exist between things and ideas are not fully addressed by the sequential, narrative form. I explore more fully here the notion of *Anschauung* or *in*sight introduced in chapter 3. This refers to instances in which we move beyond our perceptions to make inferences about things in the world. This creative type of thinking is essential not only for artistic and scientific innovation, but (I will argue), in more everyday skilled practice also. I approach this concept from the point of view of the following three topics. In doing so, I argue for the cruciality of a social dimension to a phenomenon which is traditionally thought about in terms of private, cognitive experience.

Firstly, and following on from my considerations of the significance of maps in Chapter 2, and of the various things referred to as 'imagery' in chapter 3, I explore the idea of 'visual languages' (Rudwick 1976). These have evolved for various disciplines, both as a means of communicating complex ideas, and also (and arguably more importantly) as a tool for thinking about them. I give further examples of their use and usefulness in the mental and physical mapping of places and spaces. Visual languages need to be considered with respect to the following arguments already mentioned:

- That we need to develop an ability to 'read' visual images in a similar way to that in which we read textual material (Goldsmith 1984; Kress and van Leeuwen 1990).
- That the *'meaning'* of a new mode of visual representation is largely constructed along with its *'products'* (Dennis 1989; Pasveer 1994).

They also need to be thought about in their relation to verbal languages, in particular to metaphor, for reasons that will become clear. I continue this theme in chapter 5.

Secondly, I consider competing 'models' that exist of 'mental models', (as opposed to the physical models discussed in the previous chapter). It may be however, that we use these in similar ways, and for similar purposes. Again, the division put in place between matters considered here and elsewhere is shown to be problematic. I reflect upon how all of this links with the key concepts of 'knowing' and 'seeing'. Thirdly, I consider modes of inference. I argue for the usefulness of the abductive model, in which we make construals that go beyond what is 'known' via visual or other modes of perception, or through 'the rules' that pertain to a particular practice.

4.2 Visual languages...

Gombrich (1960) argued that, because the relationship between an object to be depicted and its visual representation is never straightforward (despite any intentions that the illustrator may have towards 'realism' or objectivity), any form of artistic representation is in essence a visual language. Martin Rudwick (1976) traced the emergence during the nineteenth century of a 'visual language' (represented by a widening range and increased number of illustrations) for the evolving discipline of geology. This came about largely because of the discipline's concerns with phenomena that could not be communicated adequately by words or mathematical symbols alone. Alongside this role in the communication or description of complex phenomena however lies another (and arguably more important) one; that of inferring (or theorising) beyond what was known, or could be seen of them. This process was a social one, of working towards a consensus about the nature of these phenomena.

Wittgenstein (1953) argued against the possibility of 'private languages'. His argument is based on the idea that language (any language, whether it be expressed in words, symbols, images, sounds - as in music, or movement - as in dance) is an inherently social activity, hence it cannot be 'private'. Following this line of contention, Gooding (1990 p.19) argued against what he termed 'epistemological individualism', and for the importance of social processes in bringing *'unruly experience into the domain of public discourse'*.

The unruly experiences referred to are individual human perceptions. Gooding used the example of the Gruber-Sehl shadow box experiment to show how people's conflicting reports of their perceptual experiences are resolved, and consensus reached. The experiment involved individual observers seated in such positions they could each see (different) shadows projected by a single object hidden inside the box. They literally saw different perspectives of the same object. Subjects therefore reported these conflicting experiences.

Not only did their perceptual experiences conflict with each other, but also with their shared belief that they were 'seeing' the same thing. Gruber and Sehl had hypothesised that subjects would reach consensus about the nature of the object in the box, and this is eventually what happened. Initially however, their reaction to such contradictory evidence was disbelief; each challenged the other's point of view. In order to reach agreement, they first each had to come to trust the other observer's reports of what they saw, and then to reconsider their own experiences in the light of them. This process involved not only finding a common system of representing and describing their experiences, but also the realisation that one's own experience may be incomplete, and hence merely one aspect of a larger possible whole. Essentially, what we see with our own eyes may be neither the whole story, not the only possible one. Observers reach consensus by constructing and exchanging 'construals' (Gooding 1990 p.23), or tentative possible interpretations of their perceptual experiences, and these are subsequently revised in line with those of others. Gooding observed that the point of this experiment for science (or for any collaborative human activity), is that what we see with our own eyes is mediated by, and made consistent with what others see.[1]

Visual languages, like verbal ones, are tools that may be used in the search for consensus of observation in science (since 'construals' may be expressed in the form of visual as well as verbal representations). Returning to our geology example, the 'visual language' of geology consists of maps, diagrams and sections with associated texts, and relates to phenomena which generally speaking cannot be seen (in the sense of being witnessed) in nature. A geological map for example, represents an attempt to depict on a 2D surface, 3D phenomena that can only really be seen where isolated outcrops of rock bare of soil and vegetation occur. It is necessary therefore for those who construct these maps to abstract (or extrapolate) further, from what is actually visible (in a literal sense) in nature; to move, as it were, from *Anschaulichkeit* to *Anschauung*.

Rudwick (1976) compared geological section diagrams to thought experiments in which it is imagined that the land is sliced vertically at a particular point, to produce a kind of artificial cutting or cliff. These sections (like the maps), are constructed from observation data but extrapolated further from what is actually visible. These extrapolations are based upon the inferences of theorists that the geological phenomena depicted continued *as they would expect from what could actually be seen.* Sections were (and still are) often shown on the same sheets as the geological maps to which they refer, to help facilitate their interpretation. Again, this represents a further example of how complementary images may be superimposed upon one another in an effort to better enable visualisation. However, it is important to take on board that, apart from these roles of showing both what is actually 'visible', and also what (it is surmised) *would be* visible, were it not obscured by surface soil and vegetation, these pictures were used to communicate ideas beyond that of the actual structural configuration of rocks and strata. As Rudwick pointed out, they also hinted at causality; the temporal and physical factors which could have brought them about. Over a period of time, these illustrations became more abstract, and the 'language' more esoteric as traditions merged and became standardised (ibid p.181).

Keller (1998) traced a similar development in the visual language that arose in the study of seismology in the eighteenth century. Although the actual causes of earthquakes were unknown at this time (and would remain so until well into the twentieth century), recent events had aroused a great deal of interest in them. Considerable controversy about their possible causes led to an 'explosion' (as Keller termed it) in the amount of research, and consequently the quantity of published material linked to these events, as authors strove to put forward their competing theories. Illustrations were used to supplement the verbal arguments proposed in these publications. Keller described the difficulties implicit in representing invisible *forces*; only their *effects* are after all visible in a literal sense. The causal processes themselves could not actually be observed. The earliest pictures in fact chronicled only these effects. They consisted of pairs of landscape paintings or drawings depicting the same area before and after the occurrence of the disaster.

Later illustrations became gradually more abstracted, or diagrammatic; less concerned with producing a literal likeness, but more with theorising about possible explanations, following the pattern described by Rudwick for geology. For example, Michell (1760) and Drijfhout (1763) used diagrams to demonstrate their theories relating to both the stratified nature of the earth, and also the invisible forces and actions involved in an earthquake. These diagrams were closely linked to the accompanying texts, with extensive cross-referencing which encouraged the reader to 'read' both text and images simultaneously. Keller, like Rudwick (1976) compared these expressions of highly theoretical constructs to thought experiments.

Moving closer in topic to my own research contexts, to an example that I have already touched upon, Pasveer (1993) described the processes by which the contents of xray images were rendered readable in terms of series of comparisons. Different representations of specific objects were compared in order to bring about a new 'pictorial' mode of depicting the body and diagnosing disease, in essence a new 'visual' language of medicine. She described the work of nineteenth century British physician J.F. Halls-Dally, who visualized the sounds produced by the chests of healthy and tubercular patients upon percussion and compared these with drawings of the shadows produced when they were xrayed, actively constructing likenesses between sounds and shadows by translating them both into drawn images. The shadows were also compared with the thoracic anatomy of dead patients as revealed at post mortem and with radiographs of skeletonised cadavers, in order to get an idea of the appearance of shadows produced by the empty chest. According to Pasveer, on the basis of such comparisons the shadows of the lungs became readable; the content of the images could eventually be read alone. However, my findings will show that images produced by radiology and other imaging technologies were rarely used on their own by my research respondents, either to make a diagnosis or to make decisions about operative procedures or techniques, but rather seemed to be used in conjunction with other images and information. This may be because Pasveer's example was a historical one. Radiology was novel at that time, as opposed to the largely accepted and standardised practice that it has now become. X-ray images had not at that time become totally incorporated into the 'body'of medical knowledge, hence their consideration apparently in isolation from other aspects of this knowledge.

This is echoed in many respects by Anne Beaulieu's (2000) study. She showed how images from MRI and PET technologies were superimposed onto anatomical atlas pictures by brain researchers, in attempts to visualise the mind within the brain. Eventually, these superimposed images came to supersede the original, atlas pictures. Beaulieu showed also how the interests of clinicians in individual, pathological brains, and those of researchers in pursuit of the 'definitive' brain sometimes came into conflict. This apparent tension between the 'actual' and the 'typical' is reflected both in general approaches to the acquisition of skills (whether these be developing 'individual' skills, or more broadly, new skills which are developing within a form-of-life), and their application within a particular and specific context. Beaulieu showed how the (undeniably 'cognitive') mind itself is in the process of becoming 'biologised' (and therefore made 'physical') through revolutionary representational, social practices.

Visual languages thus appear to play a part in breaking down the barriers that we have put in place between the physical, cognitive and social spheres. One of my aims here is to show how surgeons use a 'visual language' of their own in their efforts to map the body. I will show how my respondents used series of anatomical illustrations, radiographs and other images, presumably supplemented by their own internal mental images based upon knowledge of previous, similar cases, in order to aid their thinking and visualize the internal body. This visual language of surgeons (like the historical examples described) has evolved over time, and although it is less developed in veterinary than in human surgery, it is developing still, as further modes and forms of imagery become incorporated into its practices. As for how all of this interfaces with verbal (or natural) language.... this is the concern of chapter 5.

4.3 Mental models

In the previous chapter I discussed some of the ways in which *physical* models were used in the context of the history of science and medicine. I also outlined various psychological theories relating to our uses of mental imagery. Both of these areas need to be kept in consideration when thinking about *mental* models. Dawkins (1989, p.59) speculated upon the possible evolutionary advantages involved in our apparent ability to run mental simulations (a bit like computer simulations) of real life situations when we have to make difficult decisions involving unknown quantities in the future. We imagine what would happen if we followed each of the alternative courses of action open to us. We set up a model in our heads, not of everything in the world, but of relevant parts of it. According to Dawkins, we may see these vividly in our 'mind's eye', or alternatively we may operate on stylized abstractions of them. Like computer simulations, mental models can be run at far less cost (whether cost be counted in economic terms, or in terms of time, or energy expenditure) than that of trying things out 'for real' every time.

Are mental *models* then, the same as mental *imagery* discussed in the previous chapter? One might speculate that they are perhaps a complex, specialised kind (or system) of imagery that we use for solving problems in the world. Nersessian (1992) supports this viewpoint, suggesting that the usefulness of mental models lies in their ability (once constructed) to produce images of an object or situation from a particular perspective. From her examinations of the history of scientific change, she identified a number of 'modelling' activities, including analogical reasoning and its imagistic counterpart. It is important to point out that these activities are not necessarily separate ones, but may be used together.

Garnham and Oakhill (1994, pp 341-2) have argued that the mental models framework appears to be the most promising one in existence for bringing together research on thinking and reasoning. According to their thesis, mental models theory provides possible answers to difficult questions about the nature of thinking itself. What do people actually *do* when they think? They think about parts of a world (which may or may not be the 'real' world), and represent these parts in a mental model. This is then manipulated to reflect possible changes in those parts of the world that they are thinking about. Mental models theory was developed by Johnson-Laird (1981, 1983; see also Johnson-Laird and Byrne 1991) mainly to account for deductive inference (discussed further below). It is probably true to say however that thinking about mental models can be traced much further back than this, to Wittgenstein's (1922) 'picture' theory of meaning, Bartlett's (1932) early work on schemata, and Craik's (1943) argument that thinking depends upon people's internal models of the world.

According to Garnham and Oakhill (1994, p.14)) such approaches are consistent with the following observations:

- People find it easier to reason about 'concrete' situations. That is why many people have difficulties with the sort of abstract reasoning necessary in logic or mathematics.
- Information stored in long term memory plays a crucial role in human thought; problem solving becomes easier if we can relate the present problem to what we already know.
- People find it easier to reason from a single model; difficulties arise in the face of multiple possibilities, presumably because of limitations on the capacity of short term memory stores that are used for manipulating mental models (but see the previous chapter for consideration of the use of physical representations such as pictures in instances where multiple possibilities must be compared).

Mental models of familiar 'concrete' situations are easier to work with than those of unfamiliar or 'abstract' situations. A mental model of a current situation is structured in a similar way to models of particular situations and types of situations stored in long term memory, and people find it easier to solve problems by retrieving stored models than by manipulating models in short term working memory (Garnham and Oakhill 1994 p.342).

Schumacher's and Czerwinski's (1992 p.61) 'working definition' of a mental model as 'a collection of knowledge about a physical device, system or process' is one which has obvious value in our thinking about surgical practice. So too does that of Bower et al (1969), which broadly termed them a 'framework' for thinking about a device. Norman (1983, 1986) described them in terms of knowledge structures which are messy, incomplete and indistinct. Ehrlich (1996) discussed different ways of thinking about mental models, in psychology and cognitive science (where the term usually refers to abstractions in people's heads), and in computer-related disciplines such as Artificial Intelligence and Human-Computer Interaction, where it can refer variously to:

a) the actual model of the system,
b) the engineer's model of the system which gets embodied in its implementation,
c) the user interaction designer's model of the system,
d) the user's model of the system, or
e) the system's model of the user (often referred to as User Modelling by those

in AI who build adaptive systems and need a way to represent the target user), (Ehrlich 1996, p.225).

Again, the boundaries between the 'actual' and the 'mental' seem to be unclear. In a similar way to that in which distinctions between mental and physical *imagery* in the historical examples given have been seen to be considerably less rigid *in actual use* than one might assume in a common sense sort of way to be the case, so too the partition between the types of physical models already discussed and people's mental models is shown to be obscured (and therefore problematic) in present day computer science applications. In a similar vein, a view exists within social psychology that *knowledge and expertise* become distributed among members of a group of people who work closely together. For example, Hutchins (1990) reported how expertise in navigating large ships was distributed amongst a group of skilled seamen. This is significant because surgical skills become distributed in similar ways. I hope to offer (in chapters 8 and 9 in particular) some insights into how this may come about.

Mental models have been compared to metaphors or analogies for systems (ie, where one's mental model of a device is seen to have certain similarities to an analogous one - for example heart as pump, word processor as typewriter, brain as computer - see Collins and Gentner 1986; Gentner 1983). I discuss metaphor and analogy further in the succeeding chapter. Rumelhart and Norman (1981) suggested that such a usage may be indicative of the early (novice) stages of knowledge acquisition. However, other work (eg, Hinsley et al 1977; Halasz and Moran 1982; Clement 1988) has highlighted *experts'* (rather than beginners') uses of examples and case studies. They argued that links exist between a reliance on analogies in problem solving and the progressive construction of a mental model, and that drawing an analogy between a new system to be learned and a familiar one is inappropriate as a learning tool for novices. According to these arguments, more abstract conceptual models are more useful (and carry less potential for misleading) as initial learning devices. This echoes behavioural differences proposed by 'stage' models of skill acquisition, between novices and more experienced practitioners. Novices need 'context-free rules' that can be applied in indiscriminately every situation, whereas more skilled performers base solutions to particular problems upon similar, previous occurrences (Dreyfus and Dreyfus 1986).

Schumacher and Czerwinski (1992), in discussing this analogous way of thinking about mental models stressed that the implication is that every mental model or representation of something is in a sense an analogy for that thing, and that there may in fact be little or no difference between considering a mental model as an analogy of what it represents, and thinking about it as a collection of knowledge. They cited the work of Brown and de Kleer (1981; see also de Kleer and Brown 1983) which described mental models as 'topologies' of device models, which they took to mean a mapping between the user's mental model of a device, and the physical representation of the real system. This work stressed that it should not be assumed that an individual necessarily has only one mental model of a particular system. On the contrary, it is far more likely that we have several; of the device as a whole, of its parts, and at different levels of abstraction, for example. They also differentiated between the relatively stable types of models that we build up over an extended period of time which explain our everyday interactions with a system, and derived ones that are built 'on the run' to explain freak or unusual occurrences that we either have not come across before, or have encountered only rarely, in a system with which we are otherwise familiar.

As was intimated by the quote from Dawkins at the beginning of this section, it would appear that the thinking about mental models falls roughly into two more or less contrasting viewpoints. One strand of opinion sees them as being rather like 'pictures in the head' of the modeler, (eg, Johnson-Laird 1981; 1983), whereas another views them as rather more dynamic and interactive in nature (Gentner and Stevens 1983). These categories are (as usual) by no means absolute, as the discussion of the range of opinions that exists about them above demonstrates. It could be argued that in a sense both may be right. 'Concrete' and 'abstract' models are referred to, and debates exist as to which of these is more suitable as a learning tool for novices. It might be surmised that, whether or not it is more suitable as a learning tool, the more static type of mental model is in fact the type that is most likely to be available to the novice, and therefore the one that he or she is likely to use. This may account in part for the rule-bound patterns of behaviour that novices exhibit, and for some of the mistakes that they make and misconceptions that they have about the object or system under consideration. As they gain in experience, it may be that their mental models become more adaptable and interactive, more 'abstract' perhaps, in that they can be applied to a range of similar or related situations.

An important point about mental models made by Hutchins (1983) is that they are necessarily culturally derived. There are many ways in which a complex problem can be approached and solved, and therefore many possible mental models of it. Hutchins probably had *ethnic* cultures in mind when he made this observation, but the argument could equally well be applied to *occupational* cultures, or forms-of-life. According to this view therefore, my task as a researcher is to attempt to 'model' the problem solver's own theory of the task; care must be taken to avoid the danger of imposing my own assumptions upon it.

I have reviewed theories about the role of visual languages and mental models, particularly as a tool for reasoning, or inferring about complex phenomena. It is time now to consider inference itself in a little more detail.

4.4 Inference and logic

Inference (particularly *scientific* inference) is usually thought about in terms of inductive and / or deductive processes. I briefly discuss this terminology below. However, it is fair to say that limiting our thinking about scientific method in this way to the construction of inductive or deductive arguments has been criticised (notably by Nersessian 1992, Gooding 1996a, and Shelley 1996) for impairing our ability to make sense of what scientists actually do. I therefore continue by considering Peirce's notion of abductive inference, which (it is argued) offers a fuller and more convincing explanation for processes of innovation and discovery, not only in science but as applied to learning and problem solving more generally.

4.5 The 'problem' of induction .... (writ small!)

... the way scientists were supposed to proceed was first systematically described by Francis Bacon.... It goes like this. The scientist begins by carrying out experiments whose aim is to make carefully controlled and meticulously measured observations at some point on the frontier between our knowledge and our ignorance. He systematically records his findings, perhaps publishes them, and in the course of time he and other workers in the field accumulate a lot of shared and reliable data. As this grows, general features begin to emerge, and individuals start to formulate general hypotheses - statements of a law like character which fit all the known facts

and explain how they are causally related to each other. The individual scientist tries to confirm his hypothesis by finding evidence which will support it. If he succeeds in verifying it he has discovered another scientific law which will unlock more of the secrets of nature.
Bryan Magee 1985, p.19.

Magee was discussing the *inductive* (or traditional) model of scientific enquiry, in which theories are formulated from accumulated observation data in roughly the way described above. To use an example from my own experience, a microbiologist might observe on a number of occasions that a particular strain of bacterium grows more luxuriantly on a culture medium with a low pH (ie, a relatively acidic medium), than on other culture media. This may lead her to *in*duce (or hypothesise) that an acidic culture medium is the most effective one to use for culturing this particular bacterium. This 'fact' may then become incorporated into the body of knowledge of microbiology, either locally (within our microbiologist's own laboratory), or more formally, for example if she wrote it in a book or thesis.

This model is not of course restricted to science; it has frequently been assumed also to be the way in which we interact with the world on a much more mundane daily basis. The validity of this view has been disputed, notably by the philosopher David Hume. Hume argued (from the standpoint of logic), that the fact that something has occurred in a particular way at some time in the past cannot be taken as a guarantee that it will recur in the same way on any future occasion. This idea challenges the possibility that experiments or observations can ever be meaningfully replicated, and theories thereby 'proved'. According to Hume, the fact that people *expect* things to happen in much the same way as they have done in the past is a problem for psychology, not logic.

Popper (eg., 1959, 1977) also rejected the inductive model (or at least this particular version of it; he argued that we should in fact strive to *falsify*, rather than *verify* our hypotheses). He stated that natural laws (and presumably also our more mundane, day-to-day hypotheses) are *testable*, in spite of being *unproveable*; we can test their effectiveness by attempting to refute them. If we cannot do so, they can be taken to be correct *to the best of our current knowledge.* If they are refuted, the hypotheses can then be refined in the light of the refutation. And so on. Popper (after Wittgenstein) argued also that observation that is not itself informed by some or other theory does not and cannot exist. This 'theory-ladenness' of observation is also insisted upon by much of the work that has been carried out in science studies (eg Barnes et al 1996; Collins 1985), although it must be said that there is not wholehearted agreement with Popper upon all points linked to these arguments (see Collins 1985 pp.29-30).

Collins (1985) explored the problem not from the standpoint of how we could be certain *in principle* about the induced regularities that we perceive, but in the light of how we come to be certain about them *in practice*. He closely examined scientists' attempts to repeat others' work. In doing so he highlighted what he called 'experimenter's regress' (p.2), in which skill was implicated. As he saw it, because experimentation is a matter of skilled practice, it can never be clear whether a second experiment has been done skilfully enough to count as a check on the first. Some further test is necessary to assess the quality of the experiment, and so on.

One of the examples that Collins used was that of the American physicist Weber's attempts to develop apparatus to detect the gravity waves that are given off by massive, moving bodies in space. Detection of these is (or would be) very difficult because of their weak nature. Weber's design was based upon the premise that gravitational radiation would cause measurable vibration in an object. His design comprised a heavy bar together with a means of measuring its vibrations, plus a device that could record these measurements. The problem was, other forces would cause the bar to vibrate also, and this led to the necessity to insulate the bar from all other known and potential sources of disturbance.

Even when such insulation was carried out however, the bar would still be expected to vibrate somewhat due to the movement of its own atoms. These vibrations were recorded or traced as series of random peaks and troughs on graph paper. To detect gravity waves therefore, Weber had to decide which peaks were the result of this 'normal' noise, and which were caused by gravity waves. The problem was to decide upon some sort of threshold above which such a trace would count as a gravity wave as opposed to background noise. In 1969, Weber claimed to have detected several peaks a day that could not be accounted for by noise. However, these claims were sceptically received because he found too much gravitational radiation to be compatible with current cosmological theories. Although similar designs are still used in attempts to detect gravity waves, recent apparatus is much more sensitive. However, the problem remains: *we do not know whether or not it is possible to detect gravity waves in this way until we try to see if obtain the correct outcome. But what is the correct outcome?* In other words, we wouldn't know if we had built a good detector until we tried it and obtained the correct result, but we would not know what the correct result would be until... and so on (Collins 1985 p.84).

All of which leads us back from the realms of philosophy to a more central concern: the idea of skilled practice.

4.6 Deductive inference

Syllogism: a logical argument in three propositions, two premises and a conclusion that follows necessarily from them; deductive reasoning; a clever, subtle or specious argument.
The Chambers Dictionary.

Johnson-Laird and Wason (1977 p. 75), identified a valid deduction as one where the conclusion follows from the premises; if the premises are true, then the conclusion is necessarily true. *De*duction then, works in more or less the opposite way to *in*duction. According to mental model theory (Johnson-Laird 1981, 1983; Johnson-Laird and Byrne 1991), people reason by drawing putative conclusions from their initial models of a situation, and evaluate them by searching for alternative models that might falsify them. The term 'deduction' itself can be taken to relate to both the ability to evaluate and make deductions in this general sort of way, and also to the higher order skill of the deductive testing of more explicit hypotheses, rules or generalisations. In this type of instance, a scientist for example could be said to derive predictions from an accepted axiom system and then carry out experiments in order to test them (Miller 1996).

Going back to our microbiology example encountered earlier, another scientist might try to test out our original microbiologist's observation that a certain strain of bacteria grows best in an acidic culture medium (which she had published in a textbook, or thesis perhaps). Our new scientist might do this by carrying out a series of experiments designed to prove or falsify the hypothesis, in other words to test it out. By so doing, he could *de*duce that the first scientist's hypothesis had been correct, ... or otherwise.

Deductive processes (especially in the sense of syllogistic inferences defined above) have historically been much studied in psychology (Storring 1908; Wason 1959, 1965; Trabasso et al 1971; Wason and Johnson-Laird 1972; Erickson 1973; Clark 1974; Carpenter and Just 1975). However, there is little consensus about the psychological mechanism (or mechanisms) underlying them (Johnson-Laird and Wason 1977). Artificial intelligence has also shown considerable interest in deductive processes (eg Robinson 1965; Winograd 1977; Newell 1980).

The concepts of induction and deduction are indeed useful in explaining many of the things that scientists (and other skilled practitioners) do. However, they are insufficient on their own to account for the phenomenon of innovation or 'discovery', whether this be world-changing scientific discovery, or merely the small, routine, discoveries that form part of skilful practice. In essence, they seem unable to explain *creativity.* This brings us on to the consideration of the related concept of abduction, particularly *visual* abduction.

4.7 Abduction

In fact however, no branch of logic is a particularly valuable method of discovery....
P.N. Johnson-Laird and P.C.Wason, 1977.

Abduction is inference to the best available explanation (Harman 1965). According to Josephson and Josephson (1996 p.5), it is a fallible form of inference that goes from descriptive data (which can include perceptual data), to a hypothesis that best explains or accounts for those data. As such, it is characterised by uncertainty, and often accompanied by doubt and hesitation. C.S. Peirce (1839-1914) coined the term for what he saw as a specific and distinct form of reasoning that occurs in science and indeed in everyday life, whereby explanatory hypotheses are formed and come to be accepted. This process is important therefore in theory formation and in the interpretation of events and situations.

Josephson and Josephson (1996) argued that knowledge arises from experience by means of abductive inference, built up bit by bit from explanatory hypotheses relating to it. The abductive model is context-specific (hence my own insistence upon investigating it within specific contexts), and not necessarily based upon logic, or 'deductively valid' criteria. Johnson-Laird (1993, chapter 2) used the term *'specific induction'*, (alternatively abduction) to describe situations where an explanation for an event or situation is generated from a theory of how the world works. To return yet again to our microbiologist, she might thus form hypotheses about the best culture medium for a specific type of bacteria, from a combination of her knowledge of the physiological requirements of bacteria in general, and her previous experiences of using different culture media. Such hypotheses may prove to be correct, but (so far) are unproved. Abductions are useful then, because they generate possible hypotheses, and explanations for events. Garnham and Oakhill (1994) described how abduction can be used to learn about the world. In 'explanation-based learning' a single event of a kind not previously encountered can be explained on the basis of a theory about relevant aspects of the world. This explanation can then be generalised so that it will be useful in other situations.

All of this is interesting in relation to the models of knowledge and expertise considered earlier, and it is speculated that abductive processes may go some way towards explaining how algorithmic or book knowledge becomes transformed by actual practice as expertise is acquired. It is interesting to speculate also that by means of abductive inferences, knowledge and therefore action is possible in the face of ambiguity and uncertainty. Shelley (1996) described several examples from archaeological discovery, in which a leap was made from what might be (to an outsider) apparently insignificant visual clues or evidence, to a possible explanation of the purpose or history of an observed object. This evidence could then be ordered into a sequence - a narrative- as a means of forming a tentative explanation for what was observed.

Peirce's theory has also been applied to a variety of other complex human cognitive activities, for example by Harman (1965) to the evaluation of evidence in the law courts; by Eco and Seboek (1983) to the crime-solving activities of fictional detectives, and by Gooding (1996a, 1996b) to the field of physics, specifically to the experiments in electromagnetism carried out by

Michael Faraday. It has been applied too, to historical knowledge, and to language understanding. According to such accounts, the necessity to explain novel or uncertain observed phenomena leads to abductive reasoning which is creative and context-specific, not necessarily based in logic, and often difficult to explain or to put into words. One reason cited by Gooding (1996a p.82) for this difficulty, is the seemingly inevitable impression of a linear sequence of events given by the use of scientists' explanatory narratives, which is unsatisfactory in communicating complex abductive processes.

Shelley (1996) characterised the recognition of the significance of an object, reconstructive identification processes and the use of visual analogy as examples of abductive reasoning. He stressed the importance of expert knowledge in the recognition and identification of objects whose condition and appearance may be difficult to anticipate, such as pieces of fossilised skeletal matter, and stone tools. It is important to point out here that not all of the knowledge of an expert is communicable by means of words, as close examination of some of the literature pertaining to knowledge acquisition methods in expert systems research has shown. Some aspects may be expressed for example in skilled practice itself.

The recognition by archaeologists of significant objects has been described in terms of mental templates, or search images. As Leakey and Lewin (1992), in discussing the difficulties of recognising and identifying fragments of fossilised bone stated, *'the search image has to have an infinite number of dimensions, matching every conceivable angle of every bone in the human body'*. This has obvious parallels with my own research problem. During recent fieldwork, I was told of an operation that had taken place a short time previously, in which a dog's shattered scapula was repaired by a veterinary surgeon who specialises in orthopaedic work. The procedure, which reportedly took five hours, was likened by my veterinary nurse informant to *'piecing together the pieces of a jigsaw puzzle'*, so badly had the bone been damaged. The scapula is a bone with a complex three-dimensional shape, and the necessity for visual mental imagery of the kind described above can be imagined, in comparing the shattered, randomly shaped pieces of bone with the surgeons's knowledge (or mental template) of intact scapulae.

I argue for the value of an abductive model of inference in explaining the working hypotheses apparently formed by my respondents to account for ambiguous perceptual data during surgical operations, and the alterations made in actual practice, to plans which had been previously stated or discussed when unexpected or uncertain situations arose. Behaviour in relation to plans has been discussed already, but I would like to make a link here between planning and abductive inference. Josephson and Josephson (1996 p. 25-26) reported Eugene Charniak's comment that there are two fundamental operations of mind; abduction and planning. Planning depends upon predictions and outcomes, and while, according to Josephson it can be classed as reasoning, it is not inference, since planning decides action rather than belief. However, although he thus asserts that prediction (and thereby planning) are distinct as *phenomena*, he admits that they often become entangled as *processes*. Prediction can be used as a sub-task in abduction (for example, to tentatively 'test' a hypothesis), and likewise abduction can be a sub-task of prediction (for example, for assessing a situation). This entanglement of abductive inference and prediction-planning behaviour can account for surgeons' actions in situations that varied from what was expected, and in which the outcomes were thus uncertain. An example of this is shown in chapter 8, where a surgeon is seen to encounter - and deal with - an anatomical variation that he had not previously seen.

We have travelled a circuitous route, from consideration of knowledge and knowing, to that of seeing (in the senses both of observation and of inference), and back to the very foundations of knowledge again. This underlies the ways in which these activities are inextricably linked, and in a sense undermines the linear, sequential narrative structure that it was necessary to impose upon these chapters in order that they 'make' sense. Remember, *this* story is only one of a number of possible alternatives ......

NOTES

1 By personal communication, July 2001.

CHAPTER 5: PUTTING THE 'LANGUAGE' INTO 'VISUAL LANGUAGES'....

Sitting at a table writing words on paper; what is it that forms those words? What is going on in my mind as I write them? I have no doubt that in my case it is a matter of a series of visualizations. Not two dimensional, as if looking at a television screen; three dimensional perhaps, as if I were a thin, invisible ghost walking about on a stage while a play is in actual performance ... One might call it four-dimensional, because I am aware of their emotions and their motives as well ...
C.S. Forester (1964, p.71).

5.1 Introduction

This thesis is primarily concerned with visual (rather than verbal) modes of thinking and representation. Indeed, there have been several instances within the work so far where language has been shown to be problematic. Narrative sequencing for example, has shown limitations with regard to adequately communicating *process* and *complexity*. This short chapter is itself a case in point, since it has caused even more difficulties than normal in relation to its 'proper' place in the narrative sequence that I attempt to construct. It started out as a discrete chapter, but was later split up and became part(s) of various other chapters for a time. It has now settled (uneasily) here, closely bound up with the issues discussed before, but once again separate.

It was tempting, in view of these problems to either ignore this language issue, or to bypass it in some way. At one point I seriously considered dropping it completely, justifying this to myself for a while in relation to the pressing need to focus this work, to keep it manageable, to finish it! Language is after all the subject itself of a vast literature to which I have neither time nor space to do justice here. However, it *cannot* be ignored. It creeps into the very substance of any discussion of knowing and seeing. To ignore it would be to ignore the very crux of the problem that I have set myself. Researching these topics in a real-life context was never going to be straightforward. However, having decided in favour of doing this, and against the over-simplification of experiments, I must accept this challenge, and grasp the fact that this work was never going to be as straightforward as the sort of 'writing up'exercises, of experiments or investigations, that I was expected to carry out for my biology degree.

Even though I have separated out the particular issues discussed below, and called them 'chapter five', I do not intend that they should be considered apart from chapters two, three and four (or for that matter any of the others), but integrated. It has not been possible to separate out all reference to 'language' from the other chapters, just as it is impossible (and would be unhelpful) to remove all reference to 'knowing' or 'seeing' here. The boundary that I have placed here perhaps proves to be even more problematic than previous ones!

Besides all of this, language is so fundamental to human beings and their behaviour that any analysis of human action must at least acknowledge that fact. It is useful also to reflect upon the ways in which a consideration of language *is* of use (even essential) to my arguments, and anyway, as Forester's quote illustrates, the visual and the verbal are not so easily separated. Indeed, any attempts at a rigid separation would hint at a dualism equivalent to those that have already been examined and found limiting to any understanding of the topics under consideration, such as those of mind / body, concrete / abstract, seeing / knowing, and enculturational / algorithmic theories of learning.

5.2 'Shop-talk...'? (Lynch 1985)

My laboriously collected research materials are themselves mostly (although not exclusively) in linguistic form. They consist largely of field notes describing places and events, scraps of jotted-down or recorded conversation from the workplace, interview transcripts and so forth, and they represent a great deal of 'language work' of my own. The snippets of talk recorded in the workplace itself are of particular interest. Michael Lynch (1985) has shown how such 'occupationally specific' (p. 7) talk is instrumental in getting work *done*. He described it as 'shop talk... talk *in* the work; talk which is *part of* the work' (p. 10, my emphasis). Part of *their* work (the respondents', that is), and also part of *mine*.

We have already seen that social interaction in the workplace is important, not merely as a means of communication, but in the transmission of skills as well. It is vital also for the interpretation of novel or unusual things or events, or as

Karin Knorr-Cetina (1983, p. 117) put it, of actual 'knowledge production'. Knorr-Cetina's study of the work of biochemists showed how scientific 'facts' are established through processes of social negotiation. Although initial scientific discoveries (or at least that part where it is realised that a 'discovery' has been made) *may* be private, cognitive events, their subsequent development and (especially) their dissemination, is inherently social in nature.

Amann and Knorr-Cetina (1988) made interesting connections between visualization and language in the context of the analysis of scientific images. According to this view, 'the machinery of seeing is talk'. Image analysing talk is closely bound up with the objects to which it relates; it is not merely 'about' them, but 'with' them also. 'Seeing' in this context could therefore be described as a *verbal* accomplishment. Amann and Knorr-Cetina showed how the talk itself appeared to be 'organised' in many respects by the images themselves. Participants returned repeatedly to the same or related displays, to discuss and debate anew their content. I will later show how veterinary surgeons and nurses also gathered to look at and to talk about (again repeatedly, in 'difficult' cases), the images encountered during the course of their work, (I refer here to xray images, anatomical photographs and diagrams in surgical textbooks).

5.3 Writing 'down', or writing 'up'?

Latour and Woolgar (1979) compared the position of the social researcher in the scientific laboratory with that of the scientists they study. Both are confronted with the problem of making sense of what amounts to a 'disordered array' (p. 34) of observational information. Both too, have to solve these problems by means of language. This may take the form of the consensus-seeking talk and argument already discussed, or alternatively those other verbal processes of 'writing up', which are crucial to the transformation of raw 'data' into 'hard' scientific (or social scientific) 'evidence' or 'fact'. For language as a topic includes of course texts as well as speech, and texts as well as talk are important to my principal research setting. Texts can take many forms; scripts, letters, recipes, case notes, books, academic papers, lists and descriptions, for example. Various studies of work (eg see Garfinkel 1967; Weinstein 1975; Pack 1975; MacAndrew 1979; Lynch 1985) have shown how such texts have come to be used within 'occupationally specific competencies of "reading" and "writing"' (Lynch 1985, p.8). The meanings that texts have to participants in a particular work setting may be very different from those that they have for others outside of this particular form-of-life.

5.4 The verbal and the visual

Because my primary concern is with visual representation (and it becomes more and more difficult - and conversely, more and more necessary- to arbitrarily limit the scope of this work), I will concentrate upon written and spoken language only *as it impinges upon and interacts with* the visual. I will pick up themes introduced in the previous chapters, but temporarily abandoned since to include a fuller discussion of them *there* would have compromised too much the *narrative* structure of this work. Notwithstanding this, two major topics related to language have already been examined at some length; that of visual languages discussed in chapter 4, and that of the tacit (in the sense that they become hidden in *verbal* attempts to communicate them) dimensions of knowledge itself, in chapter 2. In addition, in the sections that follow there is a need to bear in mind the following broad themes already intimated:

- The limitations of language (for our purposes); particularly of the narrative form in the communication of process, and as far as the 'tacit' dimension of knowledge is concerned.
- The ways in which language is useful; for example as used in conjunction with images, in abstract thinking, and in consideration of the social and interactional basis of the interpretation of scientific images.

I continue by discussing the importance of metaphor and analogy, to everyday speech, thought and action generally, and to science and art more particularly. I pose the question: Is there such thing as a 'visual metaphor' - and if so, what are its relations to the 'visual languages' already considered?

5.5 Metaphor and analogy...

Metaphor and analogy are part of the common currency of ordinary language and ordinary thinking; they provide the bridge between the known and the unknown....

Helen Haste (1993), p.26.

... And part of the 'common currency' of scientific and medical language and thinking also. Haste (1993) defined drawing an analogy in terms of seeing similarities between apparently unrelated things (eg, the brain as a computer, or the heart as a pump). Analogy moves into the realms of metaphor when the comparison moves from 'as if' to making actual equivalences (ibid p.37) between the objects. When this happens, the characteristics of the metaphor, rather than those of the original object itself, start to shape our thinking about it. In this sense, analogy and metaphor are better understood (at least here, for my purposes) in terms of a continuum, rather than as two totally separate concepts. Hence I largely conceive of them together.

I consider metaphors not so much as 'figures of speech' or literary devices, (although as we will see, it may prove useful to meditate upon this use of metaphor as 'imagery' when thinking about the possibility of 'visual metaphors'), but rather in Lakoff's and Johnson's (1980) sense of 'metaphors we live by'. According to this view, metaphor (and analogy) are characterised as 'tools for making sense' of things in the world (Haste 1993). The human conceptual system itself is grounded in metaphor; metaphor pervades our language, thoughts and actions (Lakoff and Johnson 1980). In discussing this 'groundedness', Lakoff and Johnson were careful to make clear that any one concept is only *partially* structured, (and thereby understood), by means of its associated metaphor. If it were *totally* so, one concept would actually *be* another. By 'partially structured' it is meant that we comprehend one *aspect* of a concept in terms of another concept, which allows us to focus upon that aspect, and take others 'as read'. Dimensionality again!

Lakoff and Johnson (ibid) gave the example of the 'argument as war' metaphor (pp.4-6). This focuses upon the confrontational aspects of argument at the expense of possible others, such as the way in which argument *could* be thought of as cooperative in nature, the participants helping each other towards mutual understanding. Goodwin (1994, p.168) stressed the embeddedness of science itself in a metaphorical framework. The value of the 'selfish gene' metaphor (among others) to an understanding of evolution is a case in point. Hatt (1995, p.1) described how such metaphors help us make sense of Neo-Darwinist theories '*in terms that are familiar to us from our embodied experience within a cultural context*'. Conceptualizing our experiences in such a way (although the act of doing so necessarily limits the view we take of them) helps us to pick out those aspects of them that are important to us, at a given time and in a given place), which in turn enables us to categorize, understand and remember them.

Metaphors are based then, in our physical and cultural (and indeed *sub*-cultural) experience, and as such can be extended in some ways but not in others, dependent upon their context. Whole systems of concepts (and their associated metaphors) are structured in turn, in terms of other, organising (or according to Lakoff and Johnson, *orientational*) metaphors, most of which have to do with spatial orientation relating to our *embodiment* (the fact that we have the types of bodies we have and they function as they do in our physical environment (p.14). Examples of these organising metaphors are *up-down, in-out, front-back, on-off, deep-shallow,* and *central-peripheral.*

Lakoff and Johnson (1980 p.18) cited the example *'more is up, less is down',* (eg, 'high status'). They stressed the internal systematicity of these spatialization metaphors. *'More is up...* ' defines a coherent metaphorical system, not random or isolated cases. Even concepts that could be thought of as purely intellectual in nature, such as those involved in scientific theories are also often (or even always) based within these physical or cultural metaphorical systems, eg, '*high energy particles*' is based upon the *'more is up'* system. *'Happy'* and *'rational'* are also '*up*'. All of these concepts have different experiential bases, but the '*up*' concept is the same. Since verticality is experienced in many different ways, so it may give rise to many different metaphorical systems.

There is also an overall systematicity which defines coherence among (as well as within) the various spatialization metaphors. Mark Johnson (1987, p.xix) explained this orientational nature of metaphorical structuring in terms of 'image schemata', or nonpropositional, abstract structures of embodied imagination. According to Johnson, our 'embodiment'in this sense is the key to our understanding of who 'we' are, what 'meaning' entails, and our abilities to infer rationally and to be creative (ibid, p.xxxviii). He thus posed arguments against theories which involve rigid dichotomies, in particular the mind-body dichotomy characteristic of the theories of Descartes and Kant.

Different forms-of-life will have different metaphors (or understand the *same* metaphors in *different* ways). Also, new ones are continually being created. As such, metaphors, like language itself, are not fixed or static, but fluid and dynamic through time and space. Metaphors can thus be creative (or enable creativity), by allowing new understanding, and the possibilities thereby of new interpretations of our experiences, and new meanings to our concepts; as such creating new realities (Lakoff and Johnson 1980 p.145).

5.6 Metaphor, science and art...

The scientist, like the artist, interprets the world around him and within him (sic) *by making images'*
Rudolf Arnheim, 1971.

Miller (1996, p.218) too, described the cruciality of metaphor to science, as a means of extending scientists' understanding of novel phenomena by their relation to familiar ones. He gave the example of James Clerk Maxwell, whose electromagnetic field equations were based upon a comparison of the electromagnetic field to an array of wheels, pulleys and fluids (p.221). The secondary subject - the familiar array of wheels, pulleys and fluids (along with its associated visual imagery) - was used by Maxwell as a mental mapping device to enable the exploration of the unfamiliar primary subject (the electromagnetic field). This example of the use of a metaphor as a *model,* or more specifically as a *mental model* provides links with issues discussed in previous chapters.

Donna Haraway (1976 p.189) drew attention to the ways in which what she termed the *concrete* nature of models, metaphors and in turn the artifacts whose construction they inform, is essential to science because of its role in limiting the implications (and thereby the influences) of more *abstract* systems. She showed how sets of mathematical relations, for example, can be inappropriately and erroneously applied, whereas the very crudeness of what she called the 'picture paradigm' can both stimulate and constrain the imagination, thereby linking the images themselves with the words with which they are communicated, and their underlying or emergent theories. I restate here problems already discussed that are inherent in the notions of 'abstract' and 'concrete'. However, essentially I agree with the point that Haraway is trying to get across. It seems that (like me) she uses this concrete / abstract terminology in a *metaphorical* sense simply because there does not seem to be any other way (or words) with which to get across her meaning, rather than necessarily assuming a deliberate or accidental dualistic stance. Is our very language then based in dualism? Or does it merely give this impression because of its inherent limitations? This could offer a clue to the very basis of dualism (and dualistic philosophies), and the reasons why they appear to be so pervasive and difficult to escape, at least in our Western culture.

Vasseleu (1991) used the example of the development of medical endoscopy to show how what she called (after Derrida and Bachelard), the 'figurative strategies' of scientific practice, are 'constitutive of the objects whose essence they describe', (pp. 59-60). By this she meant that, not only is there metaphor in the *texts* of science, but that the manufacture of these metaphors is implicit in (and indeed part of the process of) scientific *practice* itself. So much for the cruciality of metaphor to science. What then of art? The key to this lies in the notion of *representation* which is so central to this work. Miller (1996, p.380) described how scientists, along with artists, strive to find ways to represent unseen worlds. Miller's work is so interesting because of the parallels that he drew between developments in art and science, in particular between *modern* art and science. He showed how the shift in representation in art from the figurative and naturalistic to the increasingly abstract, coincided with increased abstraction in scientific theory also. It would be tempting to linger here over some of the examples that Miller gave of this increased abstraction, both from science and from art. However, to do so here would be to digress too much; an indulgence. It is necessary to move on.

Gill Hatt (1995, p.42) argued that visualization is significant because of the ways in which it informs metaphor, citing Sontag's (1991) example of the co-development of 'modern medical thinking' with a new kind of investigative scrutiny in which the body became overlaid with military metaphors. (Think about the 'invasion' of the body by disease-producing organisms). This occurred principally through the development of microscopy, which rendered visible many things which had previously been unseen. I continue then, towards a consideration of visual metaphor, and how this may engage with the emergence of visual languages.

5.7 Towards the possibility of 'visual metaphor'.........

Mental things are alone Real; what is it call'd Corporeal,
Nobody knows of its Dwelling Place;

It is a fallacy, & its Existence an Imposture.
Where is the Existence Out of Mind or Thought?
Where is it but in the Mind of a Fool?
William Blake: *A Vision of the Last Judgement.*

Visual representations, like metaphors, can be thought about as things that stand for other things. It is interesting to speculate upon the ways in which both of these representational forms can be used, either separately or together, and in many instances interchangeably, as tools with which to think, communicate and explain. It might be useful for example to think about the bodily representations produced by medical imaging technologies, or *re*produced as anatomical illustrations in atlases or textbooks as *visual* metaphors used by scientists and medics in their efforts to make sense of the body and its pathologies.

Martin Rudwick (1976) and others have shown how visual and verbal modes of representation come together in the 'visual languages' of emerging scientific disciplines. It is interesting also to note how the word 'image' itself can be subsumed from the visual to the literary sphere. It might be useful at this point to consider some of the other disciplinary areas of which 'visual languages' may be of significance, even unexpected ones such as literature (which one might after all feel secure in considering to be purely verbal in nature). The work of William Blake for example, consisted largely of collections of poems and engravings which together form a whole, in much the same sort of way as the text and engravings in Hooke's *Micrographia.* The modern anatomical atlases and surgical manuals used by my research collaborators (and their historical antecedents) could also be thought about in the same sort of tradition.

I mention the work of Blake not purely out of personal interest, but also because of his own anti-dualist stance, in particular against the ideas of John Locke (as illustrated vehemently by the quote above). Northrop Frye (1946, p.15) described how Blake termed the unit of mental existence undistinguishably as a 'form' or an 'image'.

'If there is such a thing as a key to Blake's thought, it is the fact that these two words mean the same thing to him. He makes no consistent use of the term "idea". Forms or images, then, exist only in perception. Locke's philosophy

distinguishes sensation from reflection: the former is concerned with perception, the latter with the classification of sensations and the development of them into abstract ideas.'

The terms 'form' and 'image' may also be used interchangeably with this other term 'representation', which in turn can equally well be applied in respect of either visual or verbal modalities. The point that I am trying to make here, is that the terms 'visualization' and 'metaphor' (like 'form' and 'image') can be part and parcel of the same thing, our attempts, by the various means available to us, to make sense of our world and our experiences.

Barbara Stafford (1991, p.2) wrote of difficulties that arise in attempting to express certain ideas and relationships in words alone. She outlined the ways in which metaphor can be used to 'combine and synthesize experience that analysis has fragmented or dissected'. Sometimes though, even metaphors are insufficient, for example when discussing or describing concepts that lie too far outside the range of our embodied understanding. I have found these ideas to be of particular interest when thinking about visualization and surgery. For example, my collaborators frequently seemed to 'combine' *visual images* of varying types and from various sources to 'synthesize' the surgical body, and once this synthesis was accomplished to cluster around it, attempting to interpret the array so produced, by verbal means.

So, is it possible therefore that 'visual metaphors' exist? It is argued here that they do, and furthermore, this concept is one that has been invaluable in the analysis and interpretation of my case material.

CHAPTER 6: HOW WE GOT HERE

This chapter is divided into two main sections. In Section 6.1, I summarise the main points that have arisen from the literature review chapters. Section 6.2 comprises a discussion of the research methods used, with an emphasis on ethnography. In between, I provide a brief breakdown of the topics of the research question.

SECTION 6.1

6.1.1 Getting here...

'The only good classification is a living classification.'
Geoffrey Bowker and Susan Leigh Star (1999)

This study is centred upon a number of related propositions. The first is that, when faced with a complex task, people often construct some sort of mental image, model or map of the situation (or invoke some existing one) in order to enable them to carry it out. Secondly, they may use this mental imagery in conjunction with physical images of one or more kinds, and thirdly, that the extent to which they rely upon (or use) imagery of either type may change as they gain in experience and become more familiar with a given task. Although these propositions are not especially controversial in themselves, they have proved difficult to investigate, for a number of reasons which I discuss in section 6.2 and elsewhere.

I began by introducing the research contexts, and discussing some literary sources that are of general interest and relevance to them, but which would not fit easily elsewhere. I would like to stress particularly here the work of Pinch *et al* (1996), and also that of Hirschauer (1991). Both of these papers are concerned with surgery, the former with veterinary surgery, the latter with its 'human' counterpart. These pieces of work could be seen in a many ways as a starting point for my own. Of major (even primary) importance to both of them I feel, are the ways in which people deal with task uncertainty. I reiterate, this work is primarily about knowing, seeing and how we become able over time to do these things. As such it raises questions about the very nature of 'knowing' and 'seeing' themselves.

Although these terms are used in everyday parlance and we are all familiar with them in a common sense sort of way, they are in fact difficult to define precisely, and moreover subject to intense philosophical and psychological debate. A major interest therefore lies in what these things may actually be, and my instinct (along with evidence from the literature) tells me that, rather than being totally separate one from the other, they can in fact be seen as forming part of a single phenomenon, and as such, and for the purposes of my arguments, are perhaps better considered together. But how to investigate it? I attempt to do this in actual situations rather than by the arguably more conventional method (for this type of investigation) of psychology experiments. My reasons for this are themselves complex. Firstly I feel that psychology experiments inevitably over-simplify real-world problems, and secondly (and more importantly), although such questions are ones that are considered to be a matter for psychology (hence the use of psychology experiments to investigate them), I wish to address the social and physical aspects that they entail, as well as the purely cognitive ones (Thagard 1999).

This has already created a number of difficulties, not least those to do with the complexity of 'real' situations and skilled practice. So, is it after all possible to shed some small additional light upon their nature in this way? Time will tell, and you (the reader) must judge. One thing (and *only* one thing) is certain. I am aware that I seem to be raising considerably more questions than I am able to answer. Perhaps it is the case that some of these cannot yet be answered, either by myself or anyone else. However, I do not consider that sufficient reason not to ask them, and to think about them. So that leaves us with *un*certainty, and the potential that this would seem to have for creativity.....

One of the most pressing of the problems that I have encountered so far is that of *categorisation*, which could also be variously termed as dualism, discreteism or dichotomy, which, although so commonplace as to excite little comment in our everyday way of going about things, appears on closer inspection to be unhelpful, even at odds with thinking about the 'problem' of skilled practice. Several such groupings have come to light. Apart from the major ones of 'knowing' / 'seeing' and 'knowing' / 'doing', there is the associated dichotomy of enculturational / algorithmic traditions of learning, neither of which seems able on its own to provide a satisfactory explanation for the learning process. Considered together however, they provide a more holistic, and therefore more comprehensive view. Speaking of dichotomies, several others also spring to mind, those for example of 'mind / body', 'physical' / 'mental', 'concrete' / 'abstract', 'procedural / declarative', 'perception' / 'interpretation', '2D' / '3D', and 'visual' / 'verbal'. There is a view within psychology and elsewhere that categorisation of objects and situations along some or other lines is essential to cognition, enabling us to make sense of our world, perhaps because it reduces its complexity (see Brown 1956; Rosch 1977; Bowker and Star 1999). However, this very reduction appears to limit the understanding that it is *possible to acquire* of complex situations, and what is more appears to affect the capacity of language to communicate it.

Alan Rayner's (1997) concept of 'dynamic boundaries' seems to be one that may be of use in thinking about this problem. According to this view, the boundaries between objects, rather than being seen as solid, fixed and immutable, merely define dynamic contexts. As such they resemble the boundaries (or membranes) between the body's cells; permeable, fluid and subject to constant change. As Rayner put it, because of these properties, it is at such boundaries that life's action takes place (just as does much of the 'action' that takes place in a cell). Looking at some of these 'dualisms' from this angle permits a somewhat different grasp upon complexity. Whilst still allowing some understanding of these concepts as separate (and therefore more easily graspable) entities, some sort of an acceptance of the fact that the boundaries that exist between them may be dynamic ones of the type described above, enables an understanding also that at the edges of such a boundary situations may occur where it may become breached, and the concepts merge; also that such situations are shifting and complex, inextricably linked as they are to very specific contexts and meanings.

Linked also to all of this are problems of narrative, and of 'finding the right words' to express complex ideas. My literature review has spanned four chapters, several disciplines, and many (diverse) topics. Although it is seemingly so wide ranging, all the various concepts and subjects discussed in fact merge, interact and connect together in myriad ways; so much so that as we have seen, the actual division of this material into chapters is often arbitrary and problematic. This is partly what is meant by the 'problem of narrativity' to which I have referred, and which I attempt to escape or avoid. The narrative form (which seems to be effectively *enabled* by the sorts of categorisation alluded to above), appears inevitably to 'hide' important aspects, giving the impression of a situation as a linear, straightforward sequence of events which is often far from what is found in reality to be the case.

A major difficulty that I seem to have encountered, even in the literature review (to say nothing of the case studies of complex procedures that make up the main investigative part of this thesis), is that virtually everything connected with these topics seems to be interlinked in extremely complicated ways. Narrativity dictates however that I categorise or separate out this jumble in some sort of way, thereby enabling it to be stated in separate though linked 'chunks', whether these chunks be (variously) sentences, paragraphs, chapters or case studies. A point raised by Paivio (1991), that, since visual images are organised in a synchronous (rather than linear) fashion, they do not necessarily give this misleading impression of an orderly, linear sequence of events, has prompted me to explore the use of images for my own (as well as my research respondents') purposes. I attempt therefore to investigate their use as a means of extending the ability of narrative to communicate aspects of complexity and process that it normally conceals.

I had planned originally that in this part of the thesis, I would work through the literature review chapter by chapter in a logical sort of way, flagging up the most salient points as I go. However, I have already drawn attention to the work of Lucy Suchman (1987), which closely questions the role and purpose of such plans. She stated in essence that they are useful tools, but poor providers of explanations as to how things are actually accomplished. Like Alan Rayner's (1997) 'dynamic boundaries', plans too, are shifting and inconstant. I recently read (and greatly admired) the thesis of a predecessor in this department, in which the author did precisely this (Hartland 1993). However, narrativity has constrained me enough. Hence, I choose to breach these self imposed chapter-boundaries, and do so under the headings of visualization, representation and dimensionality. In doing so I hope to begin to illustrate how categories can merge, boundaries become blurred, and new categories (and hence new boundaries) formed. I fully anticipate though, that I will encounter the same sorts of problems with these new categories; essentially that some material will not sit comfortably within one or the other, but will seem instead to somehow inhabit the boundary between them.

Before I do this however, I restate my general research objectives.

- to consider some of the ways in which we apply knowledge in approaching and performing skilled practical tasks.
- to consider alongside this the role of mental visual images in skilled task performance; particularly their use in conjunction with more 'concrete' forms of imagery.
- to examine the ways in which people use two dimensional images to help them carry out three dimensional tasks, or solve three dimensional problems.
- to experiment with the use of text alongside alternative representational forms in the communication of process.

6.1.2 Visualization

Following Miller (1996) I have explored the meaning of this term from two standpoints, the Kantian ones of *anschaulichkeit,* or 'seeing as' in the sense of 'making something visible', and *anschauung,* that far more complex one of 'seeing that' something is as it is, and means what it does. These categories, like so many of the others that we have come across, are by no means mutually exclusive. I have discussed the idea of 'imagery', and the different meanings that this term has. For the purposes of this work, I concentrate mainly upon *visual* imagery, both 'physical' (eg, pictures, sculptures and 3D models), and also 'mental' (mental images, mental models). I have however drawn attention also to the connections that the term has with language, in particular with *verbal* imagery. Metaphors for example can be thought about in this respect, not merely from the point of view of 'literary imagery', 'poetic language', or 'figures of speech', but also because, like mental and physical *visual* images, they too can be seen as 'tools' to aid reasoning. I have argued that it is not always easy in any case to separate totally the 'visual' from the 'verbal', and that, following on from this, the concept of 'visual metaphor' is one that is of use in explaining the phenomena under investigation. As far as mental imagery is concerned, I concentrate here upon it in the sense of 'expression' rather than as 'process' (Paivio 1991), thus sidestepping to a great extent debates as to the nature of cognition itself, to which I feel that I am (and my methods are) ill-equipped to contribute.

I have focused upon various ways in which the body has been mapped, or 'made visible', in particular for (and by) medics and surgeons, by the use of 'physical' images of various types, and derived from various sources. Also the possible role that various pre-operative procedures may have as 'visual aids' for example in relating the interior of the body to the exterior, (although it is true to say that these procedures may be explained by participants in quite different ways) (see Katz 1981; Hirschauer 1991). I am particularly interested in instances where we appear to use either single images, or juxtapositions of numbers of them to supplement in some way our own 'mental' images of an object or a situation, as opposed to those where we seem able either to rely upon mental imagery alone, or apparently no longer need even this, as we gain in experience, and tasks become more familiar (Kaufmann 1990).

Just as importantly, how may *I* best approach this process of 'mapping surgeons mapping the body'? I wish somehow to go beyond narrative alone in order to better communicate this complex operation. All of this is difficult; I *cannot* presume to look 'inside people's heads', and I *will not* rely upon experiments carried out in a laboratory situation where all of 'real life' is effectively condensed to minute aspects of it. I wish to *confront* complexity, not ignore it, nor side-step it. I must therefore rely upon people's own descriptions of their experiences, and upon my own observations of them as they work, and recognise (and work with the fact) that this as a method has inherent flaws and limitations. Of particular interest are the (quite frequent) situations where these sources of information appear to directly contradict one another. These would seem to offer at least a possibility of some insight into the ways in which the mind functions in these situations. However, I digress; this is probably a matter better considered in the second section of this chapter, rather than here.

I have pinpointed possible problems that exist with the interpretation of images, particularly of those images deriving from 'new' medical and optical technologies, mainly by means of an historical comparison between the development of x-rays and that (earlier one) of microscopy. I have also alluded to my own observations and experiences of teaching microscopy, which although not part of the 'official' fieldwork carried out for this study, nevertheless yields insights that would probably not be obvious to someone undertaking a relatively short term period of observation. They are rather the result of several years of experience, and the application to it of the 'reflective' approach which underpinned my initial teacher training. It would appear that quite similar methods were (and are) required in order to render these various images meaningful, and also that these processes are essentially ones of the construction (by social means) of the meaning and content of images. From this, I consider that all such viewings are essentially subjective; related to social consensus, our own experience and expectations, and the comparisons that we make, (Gombrich 1960), and therefore that 'objectivity' of observation in this respect is an unachievable ideal, (although this does not mean that we should not aspire to it in some or other sense).

The term *Anschauung,* or 'seeing that' refers to ways in which we abstract further from our actual observations of phenomena, to make inferences about things in the world. I have considered this from the point of view of three topics, visual languages, mental models theory, and the various modes of inference themselves. Visual languages are similar to their verbal equivalents in that they have to be learned, and are subject to change over time. They evolve as a means of communication and as a tool for thought in new disciplines and areas of expertise, and are from the outset dynamic and fluid, not static (Rudwick 1976; Camerini 1993). The boundaries that exist between physical and mental imagery are particularly called into question when thinking about visual languages. I argue that many practices, including surgery have their own 'visual languages' (as well as their own verbal ones), and that these carry particular and specific meanings for specific forms-of-life.

I draw attention to the connection between mental images *per se*, and mental models, and speculate that mental models are special types of mental images (or their precursors) that allow us to focus upon, and solve problems in the mental and physical world, and which, like 'computer' or 'virtual' models avoid the costly necessity of trying things out 'for real' every time. Of interest and importance also are the following points: firstly, that the actual term 'mental model' is defined in a number of different ways, for different purposes; secondly that a person does not necessarily have just one model of a system, or even just one *type* of model (it is far more likely on the contrary that we have several, which we invoke on different occasions and for different purposes); thirdly that the boundary between mental and physical 'models', like that of mental and physical images more generally, is frequently obscure and indistinct; and fourthly that mental models are necessarily culturally derived.

In discussing inference, I have argued for the usefulness of Pierce's abductive model in thinking about discovery or innovation, over and above the inductive and deductive models which are more often used in explanations of scientific (and other supposedly 'logical') activities. I wish to extend this idea, from innovative scientific discovery to the realms of more everyday, personal discovery, such as happens as we become skilled in performing a procedure. Abduction, according to Gooding (1996a) is creative, context specific, not necessarily 'logical' and its communication and understanding are often constrained by the narrative form. Shelley (1996) characterised the recognition of the significance of an object, reconstructive identification processes and the uses of visual analogy as examples of visual abduction. He stressed that such processes are different from passive perception; however, what *is* passive perception? If the arguments about the 'theory ladenness' of observation are to be believed, surely it is not possible to 'passively perceive' something without forming some sort of theory as to what it is? Of course, such a theory may well be incorrect. Shelley also stressed the importance of abduction to expert knowledge. This is interesting, and offers a possible explanation for what happens in situations where experts sometimes 'just do' something in order to rectify a situation in an emergency, without apparently stopping to think it through in a logical way (see Benner 1994). In connection with this, Gooding (1996a) argued that it may be misleading always to prioritise the visual over other sensory modalities, drawing attention to the importance also that other sensory data may have for these processes. In chapters 7, 8 and 9, I provide my own examples of the use of aural, tactile and proprioreceptive data by research respondents, often in conjunction with visual data.

6.1.3 Representation....

This notion of representation is obviously very closely connected to, and overlapping with, that of visualization considered above. However, thinking of the boundary between them as a 'dynamic'one (Rayner 1997), rather than one which is fixed, or static, makes it easier to deal with the difficulties of organising the points that I wish to make. One way of differentiating between them (there are of course others possible), might be to take representation as an inherently social process, whereas visualisations could be thought about purely as private, cognitive matters. A key question here would seem to be 'How do practitioners represent a domain in which they are trying to solve problems'? A major difficulty would seem to lie in the perceived similarities and differences already alluded to, which exist between 'mental' (and therefore essentially 'private') and the 'physical' representations which are available for public scrutiny.

Then too, there is the modality of representation to be considered, for example, visual, verbal or some combination of the two? And in any case how do we even begin to go about representing complex phenomena such as the body? The answer to this latter question would seem to be 'in a complex way, using the range of modalities'. I choose to examine the role of representations in construing, in reaching creative solutions and (it follows) in abductive inference. I am particularly interested in ways in which representations from various sources (and modalities) may be superimposed one upon another in order to 'add dimensions' (Gooding 1996a) and the purposes which this may serve in ordering our thinking[1].

Aside from thinking about representations as physical or mental, visual or verbal, abstract or concrete 'pictures' of things (as if this were not complicated enough), I wish to consider also the notions of 'knowledge' and 'skill' here. I have discussed the difficulties inherent in defining the term 'knowledge' itself, despite its being a word that is used (and understood) in an everyday sort of way. Among the various definitions that I have considered, that of Newell and Simon (1972), which described it as a 'writing-like' representation in the mind of a cogniting agent, is particularly interesting, for the following reasons. Firstly, I am intrigued as to why knowledge is necessarily seen as 'writing-like' rather than 'picture-like'. This brings to mind the debates that exist within psychology between those who argue for the existence of analogue and propositional representational mechanisms within the brain (eg Kosslyn 1973; 1980; 1987; 1994; Paivio 1991), or propositional ones only (eg Pylyshyn 1973; 1978; 1979a; 1979b). Secondly, because of what may happen when knowledge as such is *applied*, in particular where uncertainty arises from a contradiction between one's training, or 'book' 'knowledge' and one's experience of actual practice; essentially a process which we need to go through in order to become 'skilled' in some or other domain.

Hirschauer (1991) wrote of this problem of relating 'experience to representation', although it is probably true to say that he was thinking more about physical representations of the body (for example, in anatomical atlases) than about the knowledge about it that is stored in memory (bearing in mind that this is likely at least in part, to be derived from such sources). However, he did not specifically state this, and he may indeed have had both in mind as he wrote. Most of us, for most of the time do not appear to distinguish greatly between 'physical' or 'concrete' objects such as texts, models and pictures, and their 'mental' or 'abstract' counterparts. Instead, like so many of the other entities and subjects considered here, they merge, and interact together, so much so that it becomes difficult to define precisely where one begins, and the other ends.

6.1.4 Dimensionality...

I have investigated largely from a historical perspective the different forms that visual images may take, and the different ways in which we may use them, including most notably the combination or superimposition of different types of images (Latour 1986), which could be seen in some respects as an attempt to get over the problem of dimensionality. This problem of the necessity to move between dimensions when visualizing phenomena was addressed by Tufte (1990), in considering the difficulties inherent in communicating information about a complex 3D world within the confines of the 2D space of paper, or 'flatland' as he and others have termed it. The problem was also discussed by Alpers (1983) in respect of the history of art. However, this is not the full story, since as data from sculptor respondents in chapter 7 demonstrate, 3D representations likewise seem to be of limited usefulness by themselves, and certainly cannot be seen as providing a complete solution. In a series of papers presented at a conference entitled *Displaying the Third Dimension* (Wellcome Institute / Science Museum 1998), speakers described examples of the uses of actual three-dimensional models in science and medicine. Despite their seeming advantages, these models themselves were usually only 'one' version of the various representations of a particular phenomenon that were available, and were themselves often combined with others in the same sort of way as two-dimensional pictures in actual use.

The problem of dimensionality would seem to be particularly salient when thinking about the complex, layered nature of anatomy. How can surgeons, for example, learn about it from pictures? The answer to this is that they do not, or not at least from pictures alone. Like Latour's (1986) scientists, they combine and superimpose numbers of physical representations. Actual dissections, observations of surgical procedures, and 3D anatomical models are used alongside different types of pictures; pictures incidentally which, far from being 'objective' representations of what is actually 'there', are very carefully constructed to serve particular purposes. (Gooding1996a, p.86) drew attention to a process of 'representational enhancement by the addition of dimensions' in explaining how visual representations change over time as theories develop. Gooding was writing here in the context of innovative scientific discovery. However, there is no reason to think that such a concept cannot be applied to more everyday, personal forms of discovery such as that entailed in learning.

Of additional interest to this debate upon dimensionality, is a suggestion made by Rooke (1994), that *all* visual representations are three-dimensional, in that they involve social, physical and cognitive dimensions, and that we 'see' (or interpret) them in a multi-dimensional way because of our perceptions of the overlaps between these dimensions.

To conclude the first section of this chapter, I restated the general objectives of this research. I now wish to relate these objectives to the above summarised material, and to the fuller discussions that preceded it, in breaking down my research question, and thus framing the issues which it will address more precisely.

- What measures do surgeons use to help map the internal body during operations?
- How do they come to relate their actual experience to textbook accounts and representations of the body?
- How are 2D images of the body related to actual 3D bodies?
- How do surgeons mediate uncertainty in relation to bodies?
- How do these things change as they progress from novice through to more expert stages?

Also, how do I render these problems that I set myself (seemingly so casually, at the outset) 'graphically', and in doing so, attempt to communicate more nearly their complexity? I now move on to discuss methodology.

SECTION 6.2: SOME CONSIDERATIONS OF METHOD

In this section I discuss my research methods, with a particular emphasis upon ethnography, which term encompasses a range of techniques. I describe the fieldwork undertaken, and also the experience of analysis and writing. In this research (and I suspect, in much other also), these aspects did not take the form of discrete stages or phases, but became merged together so that, in retrospect at least, it is very difficult to differentiate between them.

6.2.1 The method of ethnography

'It ... is my belief that any group of persons - prisoners, primitives, pilots, or patients - develop a life of their own that becomes meaningful, reasonable and normal once you get used to it, and that a good way to learn about any of these worlds is to submit oneself in the company of the members to the daily round of petty contingencies to which they are subject'
Erving Goffman (1961: ix - x)

This quote from Goffman gives a pretty good idea of how to go about collecting ethnographic data (or at the very least it represents a fair description of how *I* went about it). Nigel Fielding (1993 p.154) described ethnography as *'A form of qualitative research which combines several methods, including interviewing and observation.'* According to Fielding therefore, it is not *one* method, but a combination of several. Denzin (1970) likewise referred to it as *'A curious blending of methodological techniques'*. McCall and Simmons (1969 p.1) went into a little more detail. For them, it includes *'Genuinely social interaction in the field with the subjects of study, some direct observation of relevant events, some formal and a great deal of informal interviewing, some systematic counting,some collection of documents and artifacts; and open endedness in the direction the study takes'*. Basically, all of this is what I did. Even this fairly exhaustive list does not however capture the *essence* of what ethnography is, or what an ethnographer does. Geertz

(1973 p.30) following Gilbert Ryle, defined it as 'thick description'. I feel that this term captures its essence (and what I have tried to do) rather well.

Many ethnographic studies are pleasurable and satisfying to read, almost like a good novel. Neither does the similarity end here. Atkinson (1990, p.2) described how in ethnographies, like novels, the *'narratives and descriptions, the examples, the characters and the interpretive commentary are woven together in a highly contrived product'*. Ethnographies it seems, are explicit and acknowledged constructions. As an approach, this seems a good deal more honest than those that profess objectivity. This does not mean of course, that ethnographers do not (and should not) strive for this ideal, taking pains to guard against undue and misleading bias. Geertz (1973 p.30) cited Solow's very pertinent analogy between the quest for objectivity in research and asepsis in surgery. Like perfectly aseptic environmental conditions in the operating theatre, objectivity in research is impossible to achieve. However, one would not *'perform surgery in a sewer'!*

Fielding, whilst calling attention to the drawbacks of the method (the most pertinent one for me being the difficulty of creating a coherent analysis from the reams of data of different types that one has to deal with), stressed its particular value as a *'method of discovery'* (ibid. p.155), in novel contexts. This context is certainly a novel one, and what I, like Stefan Hirschauer (1994), have attempted to produce in relation to it, following in the traditions of anthropologists such as Geertz, is a *'thick description'* of what I observed, what I was told, and most significantly of instances where the two seemed to be in direct contradiction to each other. I describe the process below. My account is divided into three sections, on data collection, analysis and writing. These three stages are by no means distinct however, either in the doing, or in the reporting.

In addition I describe some early introspectionist experiments, and a pilot 'micro-study' which I carried out early on when access to veterinary practices was temporarily curtailed, in order that I could begin to try out methods and define initial concepts. This latter study forms the subject for chapter 7. My major concern in this section is to show how this research has evolved over time, rather than to enter into prolonged discussions and defence of my methods. I justify this on the grounds of the original nature of this work. There simply is not a standard, approved method for carrying out a study of this nature. In many ways it represents in total a series of experiments. It seems however odd in some ways that something as fundamental as human skill requires to be researched by means that apparently hover on the forefront of what is possible, and outside of what is conventional. However, this can be explained in terms of the *verbal* character of much academic research, and the *non-verbal* character of many skills.[2]

6.2.2 Collecting the data: into the field

At the commencement of this study, I had assumed (with some justification I felt), that access to veterinary practices would be unproblematic for me, because of the large number of contacts that I had amassed as a result of my previous employment[3]. Indeed, I was offered an opportunity almost immediately to spend a two week period in a practice in which a former student and also a former colleague worked as veterinary nurses. This practice was of particular interest because its principal carried out orthopaedic referral surgery, as well as general veterinary work. As the year advanced however, and I busied myself working to fulfil the various requirements of the Masters degree in Social Research that I was following as part of my research training, the contacts that I had made over several years began to dry up. The orthopaedic surgeon for example, was in the process of moving his practice into a newly-built veterinary hospital in a different part of the town in which he was based. I felt that my presence at this time, even if permitted, would have added to the inevitable upheaval. Another contact had sold his partnership in a local practice, and gone to work as an administrator for a major animal charity in another part of the country. This made opportunities for further placements difficult to come by, especially since the type of research that I was intent upon carrying out is unfamiliar for the most part to veterinary surgeons.

Ethnographers have historically tended to concern themselves mainly with groups of people who have (or had) relatively little power to resist (should they wish to do so) the research process, and this has led to criticism from various quarters. The 'exoticising' of ethnic cultures for example by some anthropologists for example, has been implicated in establishing 'primitive' human life as 'other' in the eyes of the 'civilised' European world, thereby serving or justifying colonialism (see Asad 1973). More recently, deviant groups (particularly inner-city, working class youths) have been the subject of ethnographic study, for example by the Chicago School of sociology (Shaw and McKay 1969). Such groups can also be viewed as lacking in power, in many respects, to resist being studied. The people who are the subject of this study however belong to a relatively powerful professional group, and although the ethical issues involved are considerably less contentious (though by no means entirely absent), this was not without its own problems.

For several months I tried to forge new contacts, initially with little success. The veterinary form-of-life has little or no tradition or experience of social research, and I became increasingly pessimistic about my chances of finding practices which would allow me access. The fact that I found it so difficult to explain in lay (or indeed any) terms exactly what I was trying to do, due in great part to the exploratory nature of my research topic, did not help. I sent off batch after batch of letters in an effort to obtain observation opportunities, and in the meantime applied myself to other research activities referred to above, and discussed in more detail further on.

Eventually however, my persistence in attempting to make contact with prospective respondents paid off. After a brief absence from the department, I returned to find waiting for me a letter from a veterinary practitioner in a nearby town, inviting me observe as many surgical procedures as I wished at his practice. The only stipulation was that I telephone before 10.00 am on the mornings when I wanted to go in. Soon afterwards I received a telephone call from another vet offering the opportunity to observe operations at his practice. I cannot pretend that any overnight transformation took place. The pace of work was at times agonisingly slow, due to the necessity of fitting in with the schedules of these very busy professionals, but at last the work started to take on a pace and a life of its own.

6.2.3 The experience of fieldwork

Fieldwork, in my experience at least, is a far cry from the impression given by the tidy narratives with which most research is reported. On the contrary, I found it to be a difficult, messy and frustrating process, which could be likened to trying to piece together concurrently several jumbled up jigsaw puzzles without the benefit of the pictures on the box lids to follow. It was often a physically exhausting experience, as well as a mentally tiring one. My initial period of observation was spent standing in the very busy and stressful environment of an orthopaedic referral practice, which was at that time chronically short of space and resources with which to carry out this work. I use the term 'standing' advisedly; there was nowhere to sit, except in the clients' waiting room, which brought its own difficulties. Clients frequently questioned my presence there without an animal, and on being told that I was engaged in research, asked barrages of questions about what I was researching. They seemed to equate what I was doing with a number of popular TV documentaries related to veterinary medicine that were currently being shown, which at times caused some considerable amusement to the practice staff.

Writing of the range of difficulties that field researchers face, Lofland (1971) highlighted the issue of *marginality,* with its accompanying feelings of anxiety. Although *in* the social setting, with the agreement of the participants, the researcher is not *of* it. Geertz (1973) too, described the process of '*finding one's feet*' in the research setting as an unnerving business which '*never more than distantly succeeds*'. Frankly, I felt in the way a lot of the time, particularly since space in veterinary practices is generally at a premium. I dealt with these feelings (it was after all, *my* problem) by helping out in small ways. Staff initially seemed a little surprised that a 'researcher' did things like washing up the coffee cups and clearing up dog faeces. I later helped out in more significant ways[4], though I fought shy of total 'participant observation' *per se.* However, I sometimes felt guilty that I did not help out more than I did, particularly in the very busy practices.

Aldrich (1997) described her experiences of 'role conflict' when carrying out research in a setting in which she had previously worked. I too found that this if anything tended to add to the difficulties. However, Atkinson (1995 p.18) stressed the advantages to researchers working in specialised settings, of having or acquiring a degree of 'insider' knowledge, and I certainly found that it was extremely useful to be able to 'follow' a lot of the procedures without constantly having to ask what was going on. Also, such things as my having an awareness of the health and safety issues that relate to veterinary medicine tended to put respondents at their ease (at least as far as such practicalities were concerned), and helped lessen the impact of a stranger in their midst. However, familiarity with a research setting clearly has its drawbacks as well as its advantages.

Another early stumbling block was my reluctance to tape interactions, mainly for fear of making subjects feel ill at ease, but also because of the fraught nature of much interaction in what was often a stressed work environment. Early fieldnotes are sprinkled with remarks such as '*Still haven't had the nerve to ask if I can make tape recordings in the operating theatre. Went in, full of intentions, but what was supposed to be a fairly routine liver biopsy ended up with two surgeons, very fraught, entrails out all over the table, blood everywhere, excising a huge liver tumour. Anaesthetic not good, nurse harassed*'. Needless to say, I did not tape on that occasion! Later I did audiotape, and even videotape some procedures. It is in the end debatable however whether this really is a superior method of data collection to plain note taking, given the amount of background noise that is always present in veterinary practices, and the considerable time taken to review and transcribe tapes. One also tends to be less vigilant whilst actually in the field, relying too much on the fact that the data can be reviewed later. Perhaps in the end you actually notice less if you rely too much on the technology, and not enough on your own perceptions and intuition at the time.

Looking back, I was initially extremely (and amusingly - now) uncomfortable with the researcher role. Eventually though I found it much easier (even pleasurable) for example to sit in a practice waiting room and chat with curious clients. Sometimes they even offered interesting insights, new ways of looking at things which I had not previously considered. I still however tended to avoid any reference to 'psychology', since this tended to lead to sometimes embarrassing questions concerning the odd behaviour of colleagues or neighbours, or revelations about the problems and actions of elderly relatives suffering from Alzheimer's. The general public (or at least that section of it to be found in veterinary surgeons' waiting rooms during the observation period) seemed overwhelmingly to equate 'psychology' with clinical psychology, or even psychiatry. Even any mention of the PhD process itself seemed better avoided, since it had an apparent tendency to be transformed into 'training to be a doctor' with associated questions about, and discussion of physical ailments! It usually proved to be safer to tell enquirers that I was a teacher engaged in a form of educational research, which was after all loosely true.

On a rather more serious note, I had occasionally to contend with resentment at my having been in a sense 'imposed' upon practices by the practice principal, almost as if I were some sort of spy for the management. I managed to get around this, (at least as far as the nurses and receptionists were concerned) by making friends with them, listening carefully to what they had to say, asking their (often valuable) opinions on various matters, and helping out in various small ways. Employed veterinary surgeons on occasion however presented rather different problems. Somewhat naively, I had assumed that my presence would have been discussed with colleagues by the principal prior to my arrival. This was not always the case, and I did experience one or two difficult moments in which the person whom I had been put to observe, whilst not openly hostile, showed resentment, suspicion or nervousness at my presence.

I soon learned not to assume individual informed consent from the 'blanket' consent of the principal, but to introduce myself to each 'new' person, explain what I was doing in the practice, and ask if they minded my watching, if it was OK to ask questions and so on. Even one practice principal assumed that I was there to *'see how efficient we all are'* (despite having given willing permission for me to be there). This remark was made in a jocular tone, but was I am sure not entirely intended as a joke. I went to great pains to explain that my study was not in any sense about efficiency, that I am a researcher, not a time and motion expert in any shape or form, an identity that I certainly do not aspire to, and in any case would be supremely unqualified to claim.

In one practice in particular, it was necessary to be the very soul of discretion, simply because some members of staff were frequently to be found gathered together in huddles talking about and criticising the others. I felt that it was important not to get mixed up in this in any way. It certainly did not feel comfortable to tape any material anywhere in this practice, and in fact I did not, although I had initially sought and been granted permission to do so. I even had a veterinary student who was 'seeing practice' whilst I was there, ask my advice (as someone older, unconnected with the practice, and an 'academic' based at the University in a neighbouring city to his own), on how to deal with this type of occurrence. I suggested that he abstained at all costs from participating in this behaviour, repeated nothing of this nature that he heard, and mentioned the problem privately to his own tutor when he or she visited him at the practice.

Fieldwork did not 'officially' come to an end at any particular point, in the way that I had envisaged that it would do so. My visits to practices rather tailed off, as I accumulated more and more data, and had to apply myself to deal with it. I still occasionally visit practices, even as I am drafting this chapter. By the end of the 'main' fieldwork period however, I had carried out many hours of observations of surgical operations carried out upon domestic animals, mainly cats and dogs. These observations were carried out in five different veterinary practices, and involved many individual veterinary surgeons. As far as the nature of the various operations was concerned, I was obviously limited by the cases which presented requiring surgery on observation days. Some procedures I was able to observe only once. Other, more routine ones were observed on numerous separate occasions, in some cases carried out by different surgeons, even on different species of animals. Whilst observing, I was able to ask questions relating to the procedures, and the methods used, subject of course to constraints caused by the necessity for the surgeons to devote all of their concentration (at some times, but not others, as shown in chapters 8 and 9) to the task in hand

As well as observations of surgery, I also spent periods of time consulting surgical textbooks, watching training videos intended for veterinary students, shadowing (and helping) veterinary nurses, and observing vets and clients in consulting rooms. I also carried out interviews and informal conversations of varying lengths with vets and veterinary nurses, both during surgery and at other times. Veterinary nurses were valuable informants because a large proportion of their work generally involves assisting surgeons when they operate, chiefly by helping prepare the animals for surgery, and monitoring them once anaesthetised. I chose observation (which often approached 'participant' observation) rather than interviews alone, partly because I knew it would be much easier to get vets to allow me to watch them operate than it would be to pin them down for long periods of time to talk about what are to them rather nebulous matters. They are very busy people, often working long hours and packing a great deal of actual work into those hours.

Also, I was struck several times by the differences between what people *say* that they do, and what they *actually* do. This was not, I am certain, due to any intention to mislead. I feel that it is not a problem restricted to this particular research setting, but probably one that is inherent in this type of investigation. There are all sorts of possible reasons for this; often people try to portray themselves in what they see as the best light, they also tend to want to please, saying whatever it is that they think that you want to hear, for example. Sometimes I am sure they genuinely think that they really do behave at all times as they report. However, my evidence often suggests the contrary.

6.2.4 On observation and analysis

'As I sat and listened, I learned the answers to questions I would not have had the sense to ask if I had been getting my information solely on an interviewing basis'
(Whyte 1955)

SSK (sociology of scientific knowledge) has long argued against a common sense view of the *natural* sciences as processes whereby scientists discover by objective means, knowledge that is 'out there' in the 'real world', emphasising instead its skilled, creative and interpretive nature (e.g. Knorr-Cetina 1981; Latour and Woolgar 1979). Gooding (1990 p.60) argued that human agency is central to producing representations of phenomena (which may be mental or physical, visual or verbal), that subsequently become separated from the world of human activity that produced them. Observers have to create or achieve dualism, ie *make* the separation of representations from their objects.

As Hammersley (1993) noted, the separation of the knower from the known is unrealistic, and in some respects the *social* sciences too need to come to terms with this. My personal feeling is that an investigator inevitably becomes herself part of the context of her investigation, and leading on from that, completely detached and impartial observation is impossible. Far from being a passive, objective process, observation is an active one of interpretation. Barnes *et al* (1996) argued that even the language of observation is contextual, dependent upon existing presuppositions and assumptions which are often of a very theoretical character; and observation is in fact 'theory-laden' (p.2). It was in the light of all of this that I approached the lengthy observations that formed a significant part of the fieldwork for this study. I will not however say that it was not difficult; at times (indeed often, in retrospect) draining, exhausting, tedious, but occasionally absorbing, exciting and fun.

Unburdened by illusions of objectivity, I opted for what I will call *involved observation*; overt, not totally participant observation as such, but in no sense detached. Collins (1992) referred to his own particular take on such a method as 'participant comprehension'. I invariably and inevitably became part of the research contexts during the time I was there, involved both in interactions with my research subjects and with the work that they did. My own background, and relative familiarity with both the contexts and the types of work carried out within them undeniably assisted in my ability to follow what was going on.

In the light of all this, it follows that the data gathering and data analysis stages in a project such as this are not totally separate entities. Geertz (1973 p.26) compared ethnography to the medical diagnosis of illness. Rather than starting with observation data and attempting to subsume it under some general law, clinical inference begins with a set of symptoms and attempts to make sense of them. Although generalisation *across* cases can at times prove hazardous, generalisation *within* cases (known in medicine as clinical inference) is essential. Geertz advocated also a clinical approach to the use of theory, directing conceptualization toward generating interpretations of matters already in hand, rather than predicting outcomes, as for example with experimental manipulations.

6.2.5 Analysis and writing

'The New History of Cephallonia' was proving to be a problem; it seemed to be impossible to write it without the intrusion of his own feelings and prejudices. Objectivity seemed to be quite unobtainable, and he felt that his false starts must have wasted more paper than was normally used on the island in the space of a year. The voice that emerged in the account was intractably his own; it was never historical. It lacked grandeur and impartiality......
Louis de Bernieres 1994.

Like de Bernieres' would-be author, I have the evidence of many such 'false starts' in my filing cabinet. As intimated above, writing did and does not form a discrete stage of this research. It began with the writing of fieldnotes (which was also analytical since I had to choose which things to write down and which not to bother with). This implies selectivity, an active and subjective process. It is after all not possible for one person to record every event and conversation that takes place in such a busy environment. Hence, even in these early stages, data collection involved embryonic writing and an early form also of analysis.

I approached the 'proper' analysis of my data in the traditional way, putting events and talk into categories, comparing them, looking for similarities and differences, and this did yield some interesting insights. However, when I put aside my notebooks and files of fieldnotes, transcriptions of tapes, and the snippets of events and conversations laboriously written on filing cards (though all of these things were always close at hand for further reference, and are at my elbow now as I type), I found that the analytical process was by no means complete. In the transformation that must take place from piles of rather untidy (it must be admitted) papers and cards to something approaching a finished product, further analysis is accomplished.

As far as the writing itself is concerned, since the processes that I wish to communicate are often problematic in that it seems to be very difficult to do so by verbal means alone, I have attempted to use in conjunction with text a form of diagrammatic mapping notation; 'mapping surgeons' mapping of the body'. I feel that the narrative form in particular gives a misleading impression of linearity, that events proceed in an orderly and sequential fashion from beginning to end, which is in many ways inappropriate and unhelpful when applied to complex practical tasks. I am therefore greatly interested in alternative forms of notation which may be more revealing of the procedural, skilled aspects of such work. To this end, one of my earliest research tasks was an interview with the dance teacher at my daughter's school, in respect of how sequences of movements are recorded and communicated by dancers and choreographers.[5]

This use of visual images to facilitate comprehension of complex phenomena or instructions is hardly a new or revolutionary idea, and neither is it restricted to the performing arts. We have seen how Rudwick (1976) and Shelley (1994) wrote of similar 'visual languages' which developed early on in the histories of the sciences of geology and archaeology, due to the inadequacy of words alone in expressing certain complex configurations, and surgical manuals, and come to that the more mundane instruction manuals supplied with items of domestic equipment, also contain diagrams that *are intended to be used in conjunction with the accompanying text.* To this end I have adapted ideas that were initially applied to the work of Michael Faraday by one of my supervisors, David Gooding (1996a), in his attempts to communicate *process*.

6.2.6 The pilot study: conversations with sculptors

At this point I introduce a 'micro-study' based upon interviews with, and observations of sculptors (I use this term rather loosely to account for artists who work in three dimensions, albeit with very different media), that forms the subject matter for chapter 7. This small study was carried out as a pilot to help develop methodology and define concepts, during a period when sustained access to veterinary practices for the purpose of observing surgery was unavailable. I justify its inclusion (rather than relegating it to the depths of my dusty filing cabinet, along with many other 'false starts' and 'potentially promising papers'), because it too is concerned (at least partially) with representations of the body, and also because of the insights that it may contribute to an understanding of (particularly) the role of dimensionality within skilled task performance.

This study involved initial, hour-long, semi-structured interviews with four participants[6], plus further informal follow-up questioning. Additionally, in all cases I was able to see either finished examples, or photographs of their work, and also to observe them working for short periods of time. I have termed the participants as 'sculptors'. This terminology is somewhat loose, because in three out of the four cases, participants in fact practised a number of different art or craft forms. In the remaining case the participant sculpted in wood only. By chance, two were male and two female, although gender is not of interest here. It merely happened that these particular participants were available and willing to take part in the research. The only criteria used in their selection (apart from the aforementioned availability, and willingness to participate) was that they presently worked in three dimensions rather than two (as in drawing or painting, although some did this as well), and that they sold work. I realise that this is a very questionable, even dangerous criterion upon which to base any judgement of the quality of an artist's output. However, in the lack of any other, it did at seem at least reasonable to assume that, as people were willing to pay for their work, they were reasonably skilled and experienced at what they did. It was this skill and experience, rather than any aesthetic or artistic merit present in their work (which I am in any case ill-equipped to assess, or judge), which is my main focus.

In addition, I made a number of other 'pilot' observations, though too few data were collected to warrant chapters of their own (and besides, the necessity to limit the scope and length of the present work was becoming urgent). These included observations of lambing (the correction and delivery of malpresented full-term foetuses in sheep), carried out by shepherds and by vets, and also of the the interpretation of ultrasound images of the gravid uteri of various types of animals; sheep and cattle on local farms, and dogs and cats in veterinary consulting rooms. I also observed the use and interpretation of blood biochemistry analysis by veterinary surgeons. This is of especial interest to me, since I have carried out these analyses myself, and trained veterinary nursing students to do so. What I had not really considered before however (in the confines of the laboratory) were the uses that vets make (and do not make) of the results that are obtained. These results visualise, not the form of the body, as do those deriving from other techniques discussed, such as ultrasonography and radiography, but its function. All of these would provide interesting contexts for future research in relation to ways in which the body can be represented, and thus thought about, and known.

I mention these observations here since they formed part of the 'evolution' of this project (to borrow a term from research respondents whom we will meet in chapter 7), even though I do not report them at length. The first and last mentioned observations (of lambing and blood biochemistry interpretation) provided me in addition with the idea of using myself as a research subject, since these are procedures that I have carried out on numerous occasions. Though I did not pursue it for any length of time, or do so in anything other than a rather superficial way, I explore this idea further below.

6.2.7 Surgery as simulation

An interest in the history of psychology, particularly in the debates that surround the emergence of behaviourism, gave me the idea of making small, impromptu experiments into introspection. This technique was devised by Wilhelm Wundt and his followers in the nineteenth century. It had particular concerns with consciousness, and involved individuals' attempts to observe and analyse their own thoughts, images and feelings as they occurred. Introspection was discredited by the behaviourists for being overly subjective and unscientific (and remains contentious in some quarters today, although, since we no longer rely entirely upon behavioural cues, much 'conventional' psychological research depends at least partly upon respondents' reports of their own experiences in just such a way). My experiment is of interest, like the observations described above, because it too formed part of the evolution of this work, and so undoubtedly influenced the standpoint that I have adopted towards other forms of evidence.

This experiment involved a 'simulation' of one of the surgical techniques under investigation, that of spaying (a term used for the neutering of female domestic pets), using rabbit corpses provided by a local farmer[7] and my dissection instruments. This procedure appeared in the first instance to be not especially useful (seen in terms of a direct comparison), since dissecting a dead animal is very different from operating upon a live one. In addition, the internal anatomy of rabbits is strikingly different from that of cats and dogs, as a consequence of their different digestive strategies. Upon opening the abdomen of a rabbit, one is confronted by the enlarged coils of the caecum and colon (sections of the large bowel involved in the digestion of tough vegetable matter) which effectively mask the other organs in a way that is not found with carnivorous species. The reproductive organs were in fact very difficult to locate at all until I had removed large portions of the digestive system. It could be argued that this location would not prove nearly so difficult for a more experienced person. I am after all not a veterinary surgeon, though I do possess modest skills relating to anatomy and dissection. However, since this operation is not routinely carried out upon rabbits in the UK, it may be the case that such experienced persons are infrequently to be encountered.

This seeming failure on my part to locate the reproductive organs is interesting in that it reflected the construction of anatomical pictures discussed in chapter 3, in which organs are removed to render others visible. Such a procedure is of course not possible in actual surgery, since the intention in this case is for the animal to be kept alive and make a full recovery. Surgeons' skills, it would seem, are different from those of the mere anatomist or dissectionist! This calls into question the actual use of anatomical texts to surgeons. That they do use them is in no doubt, as will be seen in chapters 8 and 9. But how?

In the next chapter, I briefly report some of the findings of my pilot study of 'sculptors'.

NOTES

1 Gooding (1996) actually emphasises that both the processes of *adding* and *removing* dimensions are creative and important.

2 Personal communication. D.C.Gooding (2001).

3 I previously worked as a lecturer in animal science at a land-based college, developing and teaching vocational courses for those who wanted to work with animals (and who were already doing so). Students included trainee veterinary nurses, and those who wished to enter this career. Also those who wished to work (or were already working) in the agricultural sector, with horses, at zoos, safari parks, kennels, or in the pet trade for example, and occasionally also students who wished to gain practical experience with animals with a view to taking related undergraduate and postgraduate university degrees.

4 I later assisted veterinary nurses in general animal care tasks, carried out occasional laboratory analyses and helped students prepare for examinations
and NVQ assessments.

5 Thanks to Mrs J. Vosper of The Corsham School, who told me of the formal and informal methods that dance teachers and choreographers use to communicate and record sequences of movements. Although there are official' or formal notations used by some choreographers in ballet for example, many prefer to use 'informal' methods of their own devising. The example that I was shown looked a bit like shorthand, with short notes, squiggles and little diagrams.

6 'Sculptor' participants included Peter (woodcarver and walking stick maker), Christine (dress maker and theatre costumier), Barbara (sculptor and garden designer) and John (dry stone waller and walking stick maker).

7 These animals were culled as a result of large numbers of them damaging crops, NOT for the purposes of this experiment.

CHAPTER 7: BUILDING BODIES: SCULPTURE AS PRACTICE, OR 'SCULPTURAL PRACTICES'?

''I'd like to be able to carve my results on a Henry Moore statue", she was to say later, meaning not only that the results should be good enough and enduring enough to justify such an act but that statue and inscription together would bear witness to the same creativity at work in carving a sculpture and constructing a scientjfic theory'
June Goodfield, (1991, p.14)

7.1 Introduction

For Hirschauer (1991, p.279), the anatomical body (ie, the body as it is represented in anatomical pictures) is deemed to be '*an accomplishment of the sculptural practice of operations*'. If surgery can be seen thus as 'a sculptural practice', is it possible then, that the actual 'practice of sculpture' may have something to contribute to an investigation whose principal concern is with surgical operations? In this short chapter, I present evidence from pilot fieldwork observations and interviews with 'sculptors', carried out during a period when access to veterinary practices was temporarily curtailed. For the sake of this exercise, the term 'sculptor' is taken to mean an artist and / or craftsperson who works in three dimensions, rather than two. I am aware that the *discipline* of sculpture (as it relates to art) may define itself rather differently.

In the quotation which heads this chapter, June Goodfield and her (scientist) research collaborator drew explicit comparisons between the nature of the creative processes involved in carving a sculpture and in 'carving out' a scientific theory. It is not my stated (nor implicit) intention to effect any such comparison here between these two groups of participants (surgeons as 'scientists', or sculptors as 'artists'?). My interests in these practices are bound up rather with skilled task performance. It is nevertheless fairly inevitable that some differences will emerge, (and more notably perhaps, some similarities, since, because our society for the most part places science and art in separate, and often conflicting categories, the differences are highlighted quite effectively without any input from me).

Several factors of potential interest emerge from these data. Firstly, the uses that respondents made of two dimensional pictures when making three dimensional art. This is notable because it mirrors in some respects the uses that surgeons make of anatomical pictures in their attempts to map the three-dimensional internal body during operations. Somewhat surprisingly perhaps, pictures seemed to be of rather *more* use to these artists than equivalent three dimensional 'models' which were also available. Secondly, and linked to this, the way in which the artists were observed to build up their work in stages by (literally) 'adding dimensions' (Gooding 1996a), was also interesting. Thirdly, the respondents' perceptions of when their work is or is not 'right' are useful in relation to insights that this can provide about the nature of expertise. As we will come to see, all of these issues are of relevance also to the work of surgeons, and to surgical practices.

7.2 Pictures as ideas (or ideas as pictures?): representational practices

'And when I say 'inspires' .... it inspires an idea, and it may not be the same as what I've seen...'
Peter, (1999)

The question addressed here concerns the number and types of ways in which artists use two-dimensional pictures in the making of three dimensional art or craft work. Some possibilities that immediately come to mind include their use as sources of initial ideas, or as Peter (woodcarver) termed it, 'inspiration', or alternatively as a device for more precisely planning their work (a bit like a blueprint), as models to copy directly, as an aid to thinking and problem solving at various stages in the execution of the work, or as a rhetorical device to persuade clients to commission work. I discuss here the uses that my respondents actually made (and just as significantly, did not make) of pictures.

7.2.1 Pictures as 'inspiration'

Unlike surgical operations, artistic creativity has no clearly defined starting point. The making of a single piece of art can be only one stage in the execution of a much larger project, and much protracted consideration and research can (and indeed usually does) precede its production. However, since our account must begin somewhere, I will begin at the point where an individual piece is conceived. It would appear that initial ideas for artistic creativity can originate from a range of sources. Respondents cited commissioning clients, previous work (their own or that of others), objects or images previously or presently seen or experienced by the artist, the suggestions or ideas of other people, the properties and constraints of the materials and tools that the artist works with, or combinations of any of these.

'Pictures' of various types were perhaps the most frequently reported of these sources of initial ideas. This is interesting in that these artists were concerned with making three dimensional objects, and 'pictures' implies two dimensions. This begs the question of why, and how they use them. One typical use was described by dress-designer Christine:

Christine; *'Well, I get a request from a client .... we talk about what she wants, we might look at some pictures in a magazine, Harpers and Queen, Vogue, something like that. She usually has an idea of what she wants, and I sort of adapt that to what would suit her... what she looks like, her figure. But more than that, like, her personality, what kind of person she is, her interests ...'*

Christine did not *copy* the dresses pictured in these fashion magazines, but apparently combined certain aspects of them with her own ideas and those of her client, and with her impressions of the client's appearance and personality to create a new and unique design. Peter too, spoke of using pictures as sources of ideas for his work in a similar sort of way:

Peter: *'Very often it may be a picture in a book or a magazine... It just happens that I saw a picture of an elephant at a certain angle. Usually, pictures of big animals like elephants you see head on, but this one was at a different angle and it was that design angle that inspired me to do the elephant. If I hadn't seen that picture, I wouldn't have done it... 1 wouldn't have thought of that, but I suddenly realised that, looking at that picture, an elephant's head can be easily transcribed into a shepherd's crook. It looked like an elephant and a shepherd's crook at the same time...'*

Connections are thus made between things that would appear on the surface to be unconnected. Peter again, had not attempted to copy the picture, although he did report having looked at it now and again to '*make sure the angles were right*'. His finished carving bore only a slight resemblance to the picture (insofar as both were representations of elephants). As sources of initial ideas then, it would appear that individual pictures 'inspire' only certain aspects, and tend to be used either together with other pictures, or in combination with other resources which may include the artist's own mental images. This calls to mind Lakoff's and Johnson's (1980) view of metaphors as tools by means of which certain aspects (but not others) of concepts can be understood. This is discussed more fully in chapter 5. Viewed in this way, Peter appeared to be using pictures as *visual* metaphors which helped him with certain aspects of his carvings, but not others.

7.2.3 Pictures as rhetorical devices

A third respondent, Barbara (sculptor and garden designer), initially denied that she used pictures as sources of ideas. Perhaps however she had misunderstood my question, since her answer seemed to indicate that she thought that I was asking whether she drew pictures as 'plans' of how she wanted or intended her gardens to look:

Barbara: *'Oh no, I can't work in two dimensions, can't draw at all on a piece of paper. I might start off with something like a bit of string for the line of a path... but I always change it...'*

However Barbara too, did make certain uses of pictures as sources of ideas, although for clients rather than for herself. She showed me a portfolio consisting of photographs and drawings of some of her gardens. The drawings were not her own work, but that of a draughtsman friend. She used this portfolio to show examples of her work to prospective clients. These very engaging pictures must (I would surmise) have served to provide Barbara's clients with ideas for how they would like their gardens to look, as well as to persuade them to commission Barbara to do the work for them. Barbara could then presumably work with, and adapt these ideas in a similar sort of way to that described by the other artists. The only difference seemed to be that Barbara apparently used only pictures of her own work, rather than those from other sources.

7.2.4 Pictures as 'blueprints'

Whilst it was fairly evident that these respondents used pictures as sources of ideas, either for themselves or for clients, all of them denied that they *drew* preliminary sketches or pictures as part of a planning or preparation process, as Barbara's statement above indicates. Christine too, refuted this as follows:

Christine: *'Oh no, I never do that, I don't think it would work.... I start with an outline idea and sort of adapt it as I go along. It develops as I make it. I used to do oil paintings like that too, when I was a student. The idea of drawing something and following that wouldn't work..'*

Having read, (and also seen examples in galleries) of sketches executed by famous artists, purportedly as 'models' for major paintings or sculptures, I had assumed prior to this fieldwork that it is a normal course of events for all artists to produce such sketches, or even a fairly detailed plan of an intended major work, in a similar sort of way as a design engineer or architect would prepare a blueprint. It is true to say also that I would expect that these models or plans would be altered or adapted, possibly quite drastically, as the work progressed. In the event however, I was surprised that they did not seem to use such devices at all.

I had by this time become a little sceptical about what respondents 'say' that they do, since observations quite often contradicted this. I am sure that this was not due to any intention to mislead, but that they quite genuinely believed that they behaved as they reported. Sometimes, as they spoke, respondents themselves realised that this was not always the case, as shown below.

7.2.5 Pictures as 'models' (to copy directly)

The fourth respondent, John, (stickmaker and drystone waller), despite initially denying that he used pictures at all, remembered that he had done so on at least one occasion whilst showing me a particular example of his work. It appeared that John had actually attempted to copy directly a design that he had seen in a picture, and this had proved to be by no means easy:

John: *'No, I don't use pictures, I use these umm* (respondent was referring here to templates that he makes himself) ...... *well, yes, that's a lie, because that round one* (describing a walking-stick handle) *I've got, you seen it? I saw that one in a picture, and it was a picture of Lord Snowdon ... And I copied that... mind you, I had to do several before I got it right, because all I saw was a stick in a picture, the side of it'.*

This was interesting. The single picture that John described, featured a side (profile) view of Lord Snowdon carrying a walking stick of an unusual design. John's claim that he had 'copied' this therefore needs to be viewed in relation to this. John went on to describe in detail a series of experiments in which he had tried to make a 'working' walking stick (ie, one that was strong enough to use without breaking), that looked from the side, like the side view of the one in the picture. He expressed surprise that this exercise had been so difficult, much more so than his usual practice of designing and working from his own templates.

7.2.6 Pictures as problem-solving devices

'Inspiration' as I have termed it (following Peter's quote at the beginning of this section), is not limited to the beginning of a project, but neither does it seem to continue unabated throughout. It is interspersed with other periods of work of a more routine nature, in a way that could (somewhat fancifully perhaps) be compared to periods of 'normal science' as opposed to 'revolutionary science' (Kuhn 1962). Fresh sources of ideas may be used at various stages during the execution of a piece, for example in instances where problems are encountered. The following example of Peter's bull's head carving demonstrates this use of pictures to solve a problem (or provide fresh ideas) in a situation where stalemate had been reached. At a client's request, he was attempting to copy a 3D model of a bull's head to the same scale. This initial attempt did not work. Other sources were required, even though by this time the work was well underway.

Peter: *'The shaping process was not going right, and I was having great difficulty. Then I was given some photos from a book, of several different bulls, not very good photos, no great detail but enough to give me an idea as to the true shape of a bull's head. I also have a great deal of experience with bovines personally. This has given me a certain mental record of what cattle look like. I* *then proceeded with carving, not really using the 3D model, but the photos and my own mental images only, not copying one of the animals, but getting clues from all of them as to the shape of the bovine head. The result was a far more technically accurate representation than the carved head that I originally started to copy. I still used the model in a way; it must have been bull-like in a way, to capture the character, but I could now see where it wasn't accurate. Its proportions gave it its character, but not its detail. The detail got in the way of my copying the proportions. Its hard to explain. I can't explain the reason for this, or the difficulty that I was having in copying the 3D figure...'*

This brings us on to dimensionality.

7.3 Mathematics in motion, or 'seeing' the third (or second? or fourth?) dimension...

In the above sequence, Peter was discussing the difficulty that he had experienced in his attempts to copy a three dimensional object directly to scale. We have already seen from John's example that copying *anything* is not a straightforward matter. In fact, respondents seemed to find copying far more difficult than following their own designs, which seems contrary to what might be assumed. Perhaps therefore copyists and forgers in the art world possess more talent than they, and others give them credit for, though the skills involved may be rather different ones!

It is certainly the case that Peter was not enjoying the constraints that trying to make a direct copy involved. In fact, he found the process somewhat frustrating, and in the end rejected it because it did not work, and turned instead to other strategies. Interestingly, the carving that he eventually produced turned out to be far superior to the one he had originally attempted to copy. The above passage is particularly interesting because Peter explicitly referred to his own mental images, describing how he used them alongside various physical ones. Again, it appears that he had superimposed numbers of physical and mental images and ideas, as Christine had done in the case of the wedding dress. Like other participants at various times, Peter also referred to the difficulty that he was experiencing in talking about these matters.

I observed Barbara whilst she also was attempting to copy a piece to scale, on this occasion a large stone sculpture. Again, this was at the request of a client rather than of her own volition. She too, experienced great difficulty in doing so, and became very frustrated. She continually measured the original, and then her own attempt with a piece of string.

Barbara: *'It's harder than I thought. I have to change all the angles...'*

It would appear that mathematical concepts such as that of 'angles' play an important role in this type of work. Allusions to measurement and to geometry were frequently made by these respondents, even where they professed not to use such techniques. Peter, for example, denied it thus:

Peter: *'No, I never measure anything. I do it all by eye. Now there's some people that carve and sculpt that have been taught the technical way if you like. I've never been taught... some people that are taught in art school may have been taught mathematically by actually measuring so that if they were doing like a bust of someone, they would actually measure that person's dimensions down to the last millimetre'*

Peter, I feel, was taking too limited a view of what 'mathematics' entails, seeing it as something that is learned in a formal situation, rather than as a particular way of thinking. This is reminiscent of studies of 'unskilled' workers' performance of similar tasks in the workplace and in the laboratory (Saxe 1992; Scribner 1997), which were discussed in chapter 2. These studies also incidentally involved 'mathematical' tasks. Like Peter, the subjects of these studies were 'experts' at performing these tasks in context. However, they had considerable difficulty in doing so when the tasks were decontextualised in the laboratory.

Measurements *can* be calculated very precisely using specialised equipment, or alternatively they can be roughly estimated with a length of string, or even by eye alone. Sometimes measurement even appeared to be used as a sort of internal sense (of proportion, or what is 'right'?), and the respondent concerned did not seem to be consciously measuring at all. In all cases though, when things were going well, measurements seemed fluid and hypothetical in nature. Indeed it could be surmised that only novices (such as art-school students perhaps?) would use them like 'rules' in an algorithmic sense.

My 'experts' evidently preferred to use measurements more in the sense of heuristics. Perhaps this offers a clue as to why copying an object to scale is so very difficult. The process requires that constant attention be paid to measurement, and this apparently leaves little available for anything else. In the normal course of events for these artists (ie, when they were not attempting to make a direct copy), such measurements as they did make, if any, had to conform to their own approximation of what was 'right', otherwise they might be changed, redone, or even rejected totally if they did not accord with other evidence or information available, or even just with the artist's 'feelings' about it.

Where a situation called for precise measurement (for instance when trying to copy a 3D object to a similar scale), practitioners seemed constrained and inhibited by it. Their behaviour appeared to revert to that of less skilled operatives. These observations (for at this stage this is all that they are) are interesting because experienced surgeons were later seen to use both the very precise measurements obtained from diagnostic equipment such as biochemistry analysers that measure minute quantities of substances such as enzymes present in the blood, and rough estimations such as those made in respect of the appropriate size of plate to fix a fracture in just the same sort of way - heuristically; to be rejected, changed, redone or just ignored if they did not fit in some way with whatever else was going on.

Perhaps unsurprisingly, *geometry* seems to be intimately bound up with issues related to dimensionality. Practitioners spoke in terms of geometry when describing how they work, and of the relationships that exist between different aspects of the objects that they were making. Peter, for example, continually spoke of planes and angles, (despite his vehement denial that he used mathematics). In the following quote he was responding to a question about how he transferred (or translated) a flat picture on a page to 3D. Peter spoke in particular of how he liked to use pictures of objects taken from different angles, and somehow marry them together in his new representation. He much preferred to use series of pictures, (even bad ones) as a model, rather than an actual 3D representation, as we saw in his account of carving a bull's head. He attempted to describe how he used pictures to 'build up' dimensions in the quote below:

Peter: *'You start in stages. And your brain has to do a bit of interpretation so as to interpret the picture you're seeing. You have to try and turn that into a 3D object, in your head. You have to try and view it as if it were 3D. And that's when you have to use your imagination a bit to try and get the proportions right... You have to concentrate on the bit you are doing at the time. And it's all about copying angles. And copying the relationships of the components with each other'.*

He continued by describing another piece of his work, a carving of a kestrel, which he had reportedly 'copied' from a picture in a book. As can be seen however, he had not really copied this picture at all, but again, apparently used it in conjunction with his own mental images and his personal knowledge about birds.

Peter: *'The picture I had in my mind was not that of the bird in the book. The picture in the book, look, the bird's head is looking forward, but with the actual finished article here the head is to one side'.*

I continued: So the picture wasn't all that much help? Peter's answer was very interesting from the point of view of the psychological experiments that have been carried out relating to mental rotation (Shepard 1975, 1978; Shepard and Cooper 1982; Shepard and Feng 1972; Shepard and Metzler 1971) which were discussed in chapter 3. As we see here, Peter reported that he had 'rotated' the bird's head (ie, from its position in the picture), mentally:

Peter: *'It was, for getting some of the detail of the head. It doesn't matter* if *the head is looking to the side, or straight ahead, you still need to look at it from a proportional viewpoint. Getting those proportions that I keep on about... Doesn't matter which position the head is in, those things stay fixed. The relationship between the head and the body isn't fixed, so you can put it wherever you like.., because a bird can move its head. As long as I know the relationship between the head and the body I can make it look over its shoulder.... its easy. You just turn its head, so it is looking over its shoulder.*

This did not sound at all easy to me, either to do, or as a concept. It presents an interesting parallel also with the Gruber-Sehl shadow box experiment reviewed in chapter 4, in which participants had to guess the identity of the hidden object in the box from the shadows that it cast. In the original experiment, participants worked in pairs, each individual describing the particular aspect of the object that they saw to a partner who was seeing a different aspect. Together they had in this way to arrive at the identity of the (three dimensional) object in the shadow box, from the different (two dimensional) images that they could see (for fuller discussion of the Gruber-Sehl experiment, see Gooding 1990). However, two successive groups of undergraduate students whom I have assisted with small research projects related to this, have presented the problem also to single subjects. These lone subjects had to look at first one (two dimensional) shadow, and then another, in a similar sort of way to Peter's description of making the kestrel. They were required to combine actual physical images of all available aspects of the hidden object, whereas Peter had available to him only one such physical image, the picture in the book. Others were supplied from his own mental repertoire. However, it would seem that he combined them in the same sort of way.

It could be surmised that my artist respondents, like the Gruber-Sehl participants, also worked two-dimensionally most of the time, even though they were actually making (rather than merely trying to identify) three dimensional objects. Like Gruber's participants, they seemed to have to concentrate on one aspect (or 'plane') at a time - related to the part they were presently working upon - even though they somehow at the same time retained an awareness of the whole. They seemed toswitch between different 'views' or aspects of the object. As Barbara describing an almost-completed garden put it:

Barbara: *'When you've got several bits nearly finished, you sense it is all connected, but I can't stand in the roof and see it all at once. I look from all round the house, round every window quickly, as a sort of a summary ... to me, its all one thing, what's it like to walk through it, it has to flow smoothly and freely link with the next bit...'*

This evidence seems important. What it seems to indicate is that, although we may 'sense' in two dimensions, we actually 'perceive' in three.

7.4 Art as evolution?

Respondents frequently referred to processes by which their work 'evolved' over time. This 'evolutionary' process seemed to be driven by various combinations of ideas and images, and it is fair to say that the properties and behaviour of the materials used appeared to interact with these also. Respondents' initial ideas were incomplete; they developed over time, becoming more complex, as well as changing (as in biological evolution). Like biological evolution, the more complex the object and the ideas, the more marked appeared to be the evolutionary process, and the longer it took.

This application of the metaphor of evolution in a situation where phenomena that are difficult to describe verbally are being alluded to, is suggestive of uses that may exist for metaphor and analogy in communicating some of the tacit dimensions of knowledge. Metaphor and (associated) analogy seems far more useful in this respect than propositional language, or narrative. Helen Haste's observation that metaphor can provide a 'bridge between the known and the unknown'(1993, p.26) may be extended to encompass 'the verbalizable and the unverbalizable', surely areas where the boundaries between what is 'known' and what remains 'unknown' become blurred, and merge together by the very fact of their mutual incommunicability. This is interesting in that surgical operations also 'evolved'; initial plans and ideas were often adapted for example to account for anatomical variations, or variations in actual injuries which had not been apparent on radiographs, or when an attempted intervention simply did not work.

Over the course of hours of observation, I became conscious of distinct stages that seemed to occur during the 'evolution' of these artists' work. They appeared to vary in length both temporally, and in respect of the progress that a particular stage may make towards the eventual completion of the piece. Fresh ideas or images (or combinations of them) seemed to be used, generated or incorporated at these transitional stages.

There may be a link between the individual 'aspects' of a piece of work to which the artists referred, and these transitional stages that seem to occur in the evolution of the work. Perhaps it is the case that a particular stage comes to a close once work has been completed (or at least, completed up to a point) in one of these aspects or planes. This may offer a clue as to why practitioners seemed to prefer to work from a number of 2D pictures rather than from an actual 3D object. It may be easier to visualise the planes in isolation from such pictures (ie, one picture equals one plane) rather than to break down a solid 3D object into its separate planes. It may also explain why practitioners seemed to have to concentrate far more upon precise measurements when working from, or trying to copy, a 3D model. If only one 2D picture (as opposed to a number showing different planes), is available, practitioners may have to experiment, as John's experience with Lord Snowdon's walking stick showed! Peter's evidence relating to the bull's head showed moreover that they may be able to fill in the 'gaps' in the available representations from their own experience (if of course they are representing an object with which they have experience).

Respondents used three nouns (piece, aspect and dimension,) to refer to the dimensional sub-division in this respect of a piece of three-dimensional artwork. Although strictly speaking these are terms which can be defined differentially, they are used in this instance to refer, I think to the same thing (since respondents seemed to use them interchangeably). I thus consider that the single term 'dimension' could be usefully substituted for any or all of them. It would seem that, in carrying out 3D tasks, these artists worked in only two 'dimensions' at any one time. However, whilst doing so, they were apparently somehow able to switch their thinking between the part (in 2D) they were working on, and the (3D) whole, both in line with transitions between these stages, and also within them. It is also possible however that, despite what respondents *said* about what they did, they may nevertheless have been imaging in 3D, but articulating, verbalising about only two at a time.

I have attempted to convey a sense of the complexity of balancing the idea of the whole (ie, of a piece of artwork) with that of the part that is presently being worked upon. The artist's task can be seen as 'swapping' between part and whole as the work progresses. Perhaps this can best be described in terms of series of visualisations (except that they are not always necessarily 'visual' in nature). Perhaps, like Alan Rayner's (1997) 'dynamic boundaries', the boundaries between these transitional stages, where the part is linked back to the whole, or to the next part of a piece, are in a sense the most important and useful ones in seeking an explanation for this process.

7.5 Evolution, ideas and materials

Ultimately, what can eventually be accomplished is dependent to a great extent upon the properties of the materials that are used, and the ways in which they behave. When combinations of materials are used, their interactions are also a factor. Materials are not necessarily always a limiting factor however, since they can generate creativity, as well as constrain what can be achieved. As Peter put it:

Peter: *'Depends on what you got, depends on what you make'.*

Materials (as well as images) can be combined in novel ways to produce original results. Respondents stressed the need to work *with* the materials, rather than merely imposing form upon them. In this way, they too can be said to be 'organic' in the same sort of way as the process by which objects evolve. They take on a life of their own, and become part of this evolution. The materials and the ideas merge together in the production (or evolution) process. This (not always expressed) knowledge about the materials that these artists used, brings us on to consider the part played by expertise in our unfolding story.

7.6 On expertise: the search for 'Rightness' (or visualization in action?)

'Life 's the messy bit... art is where we have the chance of getting it right... '
Jeanette Winterson, 2000

Like Winterson, my respondents frequently spoke of the importance of (and the difficulties involved in) getting things 'right'. Considerable efforts were thus directed towards achieving 'rightness'. In chapter 2, we saw Benner's (1984) description of how expert nurses would seem to know instinctively which course of action was the 'right' one to take in a given situation, without necessarily being able to explain either why it was 'right', or how they had known that it would be 'right'. To artists, this preoccupation with (and sometimes, search for) 'rightness' can be absorbing, and also frantic, frustrating, exciting; indeed it can be likened in some ways to experimentation (and can even involve thought or practical experimentation in a literal sense). In a conversation with John on (his favourite) topic of drystone walling, he described it thus:

John: *'...well, when you pick up a stone and you place it, it doesn't mean to say its going to go there. And you can throw it to one side and pick up another one. And then after a bit the stone that you've just thrown down will fit somewhere else'.*

I elicited mild surprise at this comment, having assumed that drystone walling was merely a matter of piling stones on top of one another. His emphatic response was:

John: *'Oh, no, no... when you're building a stone wall they've got to sort of sit right, they've got to cross over. You put them on top of one another, the next thing your wall will be falling down. Oh, its quite an art... but that's how it is, each stone you pick up, it don't mean to say you can just go along putting it on, its not like that... Building a brick wall, you just slap some cement and every brick will fit, not like when you're doing stone walling. Its got to... the stone's got to be right. It's almost like a jigsaw puzzle... it's no good trying to get that piece in there if it doesn't go... Yes, you see, you know. You think no, that doesn't look right there, and you can be ... you know, but it just doesn't look right there... perhaps you just have to knock a little bit off of it... to fit in... no, its got to be right'.*

Rather like surgery, (or research), in fact! 'Rightness' in this sense is perhaps best described as chasing an evolving idea (or more likely ideas) as described above, rather than necessarily trying to make, or represent an object (although this is obviously happening as well on a more practical level). Barbara stressed the holistic nature of this feeling. For her, it was not explicitly concerned with the individual stages of a project, but neither did it continue unchanged throughout. There was (as described earlier) a sense of the importance of the experience and familiarity of the artist of the use of his or her materials, and the ways in which they behave, although of course people experiment with new ones. It is important to know what will and will not work, and what to do if it does not quite work, and much of this knowledge can only be gained by experimentation. Speaking of her youthful experimentation with various crafts, Barbara described the gaining of experience with a technique thus:

Barbara: *'I remember when I started out, I remember working in a craft shop. It certainly wasn't 'art' at that stage. I used to practice macrame, using finer and finer threads, working through the whole range of what you can do with a bit of string. I was searching for a special ingredient... One day, I was making a lampshade using fleece, which didn't lend itself to a linear weave. I stayed with this excitement, a breakthrough from having to use a formal structure.... moving on from the craft to the freedom to use it...'*

This state of rightness it would seem is often although not exclusively related to the visual, or what 'looks right'. Barbara stressed also a sense of 'internal balance' that is more important to her than, and precedes, the visual. There seem to be many aspects involved in 'rightness'. It is hard to express in words, and is related to expertise. Experts just 'know' what looks or feels 'right'; they strive for, and recognise whether or not it has been achieved, even though they may not accurately be able to describe, or define it. Thus it can be very difficult to explain to others what is 'right'. In the quote below, Christine was responding to a question about how she knew whether or not something was 'right' in her own field of costume design:

Christine: *'By the shape, reference to historic style. Emotional style, the feelings that something gives you; the colours, tone, texture, what feels right. Colour, like different shades in the same colour range. I can't describe it verbally, not accurately. You can only do it by eye, because people would have different ideas. When I used to do my handspun jumpers, I got Susan to do some of the knitting up for me. But it didn't work. It wasn't her fault. I couldn't describe to her how to put the colours together harmoniously. She got the wrong ones next to each other, and I couldn't explain to her properly what was wrong..'*

This is a topic which would be very interesting to investigate further in a future piece of work. I have not been able to interview novice sculptors for the present research, and indeed to have done so would have deviated too far I feel from its stated purpose. It is (I have found) very easy to get sidetracked, and to follow areas of interest that arise from fieldwork material. However, there comes a point where it is necessary to recognise interesting observations of this nature as precisely that, and relegate them to the realms of future research possibilities.

7.7 Sculpture as practice: a general synthesis:

This small study is limited both in scope and in duration, and in many ways is merely speculative. It is also however very interesting, both for possible further investigation as a future research topic, and in consideration of that of this research. Of especial interest is firstly, the various ways in which respondents used two-dimensional pictures to help them make complex, three-dimensional objects, and the problems that these entailed. Pictures were used by these respondents as sources of ideas, as tools for thinking about aspects of the piece under construction at various stages, and as rhetorical devices to persuade clients to commission work, but not (apparently) in the sense of plans or blueprints. Their use as models for copying directly was also seen to be problematic. However, whether this is related to the fact that pictures are two dimensional, and 'sculptures' three, as was apparently indicated by John's attempts to 'copy' the walking stick carried by Lord Snowdon in his picture, or rather, as we saw with Peter's and Barbara's attempts to copy three dimensional objects, whether it is a problem with copying more generally, is open to debate.

Respondents preferred to use *combinations* of images rather than single ones. This combination or superimposition of images often took the form of a number of pictures used together, each contributing information about some or other aspect of the subject in question. Pictures were also observed or reported however, to be used in combination with other types of images, such as three dimensional models or the artist's own mental imagery.

Secondly, and related to this, the study is interesting in its consideration of the ways in which we deal with dimensionality and complexity. The idea is put forward that, when we are occupied with a complex three-dimensional task, we only work with two dimensions at a particular time. This may offer a clue as to why numbers of superimposed two dimensional pictures were apparently preferred by respondents to single three dimensional models. It would seem however that a major concern of respondents using series of superimposed two dimensional 'models', was with the uncertainty which surrounds the relationships (or perhaps as respondents called them at times, the 'angles') between these two dimensional aspects in respect of the construction of a three dimensional object.

The mathematical thinking that is apparently entailed in both this switch between dimensions, and the uses that artists made of measurements (and their inherent problems), elicited interesting parallels with some of the aspects of surgeons' work reported in the following two chapters. Measurements, it would seem, can be used in a very precise manner (like an algorithm), or in a far more rough and ready fashion (more heuristically), by both 'artists' and 'scientists'. Experienced practitioners demonstrated unwillingness to 'believe' the evidence of measurement if other evidence appeared to contradict this, even if, as we have seen here, the respondents had problems in elucidating exactly what this other evidence comprised.

This brings us to consideration more generally of things that are difficult to 'put into words', both in respect of respondents' experiences, and for my own purposes here. David Gooding (1996a, p.92) mapped the complex electro-magnetic experiments of Michael Faraday onto matrices, in order to avoid to some extent, the constraints of narrative sequencing in communicating these complex ideas. Working from records (representations) of real-time processes, he claims that he can identify and represent 'enhancement and consolidation' processes, showing where movements have been made between dimensions, and also where abductive inferences to new phenomena have occurred by means of this device.

Attempting this with some of the present data however resulted in too many moves back and forth between dimensions, (reflective perhaps of the contrast between historical data and real time events). This resulted in messy, unclear and unsatisfactory representations. Faraday's records (of real-time processes) would be expected over time (since they represented some years' work), to have eliminated some of their original complexity, perhaps so that he could then use them as tools for further thought or experimentation. They were thus likely to be at a considerably more refined (or abstracted) stage of development than the data hastily assembled for this pilot study.

Professor Gooding was presumably now able to abstract on still further from Faraday's own representations in the construction of his matrices. The present work (or at least this section of it) would require then, considerably more refinement and *re*presentation before I could produce diagrams of this type. I have neither the time nor the space for this here, although it remains an interesting possibility for a future piece of research. I would however like to propose the following diagram to represent (an initial) visual schema for sculpture:

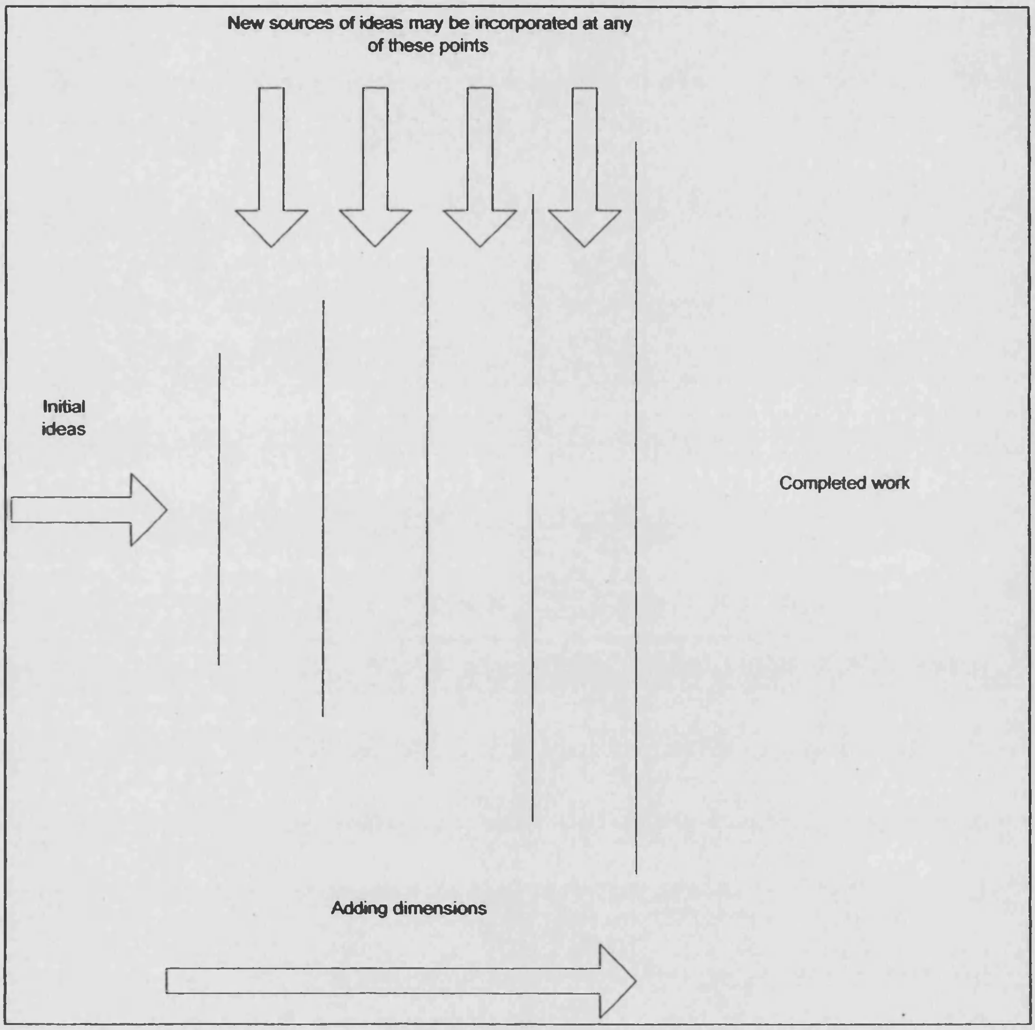


Fig 2: Diagram proposing an initial schema for sculpture

This diagram is intended to represent the making of a piece of three-dimensional artwork from its initial conception to its completion. This is represented as a series of stages (by the vertical lines), to indicate the reported 'evolving' nature of the work. These lines vary in length from left to right to indicate the work's progress towards completion. The diagram is an attempt to encapsulate and summarise the evidence about this process put forward by these four artists.

It is time now to turn to surgery.

CHAPTER 8:

TAKING THINGS APART: OVARIO-HYSTERECTOMY - A STUDY OF SOFT TISSUE SURGERY

'Writing about work is a way of getting close to how people think'
Michael Ondaatje, 2000.

8.1 Introduction

In this chapter and the next, I examine examples from my fieldwork studies of veterinary surgery. I begin with observations of the 'soft tissue' surgical procedure of ovario-hysterectomy, or 'spaying'. These latter terms refer to the neutering or desexing of female domestic pets. Surgeons differentiate between such 'soft tissue' surgery and the orthopaedic operations described in Chapter 9, on the basis of the 'more tactile' nature of soft tissue surgery. This expression refers to the particular importance of touch sense (in addition to vision) in carrying out these procedures. I am indebted to US veterinarian and historian Susan D. Jones for pointing this out[1]. Research respondents also alluded to this distinction; frequent references were made for instance to the importance of the 'feel' of the organs and tissues during these procedures. My reading and my own observations have led me to this conclusion as well. However, Dr Jones put it more succinctly than either they or I.

I have used this distinction as the basis for dividing this chapter from the one which follows, although as usual, other possible criteria for division or categorisation exist. For example, operations can be classified according to the location within the body where the procedure is performed (such as thoracic or abdominal surgery), or alternatively with reference to particular organs (cardiac or hepatic surgery). Surgeons in human medicine specialise along just such lines. *Veterinary* surgeons however rarely specialise in the same sort of way, or to the same extent. Another method of categorising different types of surgical operations was contributed by BM, a veterinary surgeon research respondent. He grouped them according to the circumstances under which they are carried out:

BM: *'There are basically two different types of procedures. Firstly when you have an animal booked in, for example, for the removal of a mammary tumour. You will have done a general health check, discussed the possible implications and benefits of the surgery with the owner, and may well also have carried out a precautionary blood profile, chest x-rays and so on. You know more or less what you are dealing with. The second type of situation is where the animal presents as an emergency ... You have to start from scratch, take a history, do a physical examination, blood tests, x-rays and so on, all in a situation of some urgency....'*

BM was alluding here in the first instance to situations in which any necessary diagnostic 'detective work' has been done in advance, and the surgeon is in the position of carrying out a pre-planned procedure whose outcome is likely to be to a large extent predictable. I have termed this 'Type 'A' surgery'. In the second instance, he referred to high risk 'emergency' situations where surgeons do not really know what they are up against, and have to start from scratch. I have termed this 'Type 'B' surgery. In such cases, immediate first aid treatment to preserve life or relieve pain is often imperative. Only after such measures have been carried out will the surgeon try to ascertain the cause of the problem, and make decisions based upon this about suitable treatment regimens.

Despite the considerable problems that I experienced with categorising, and thereby ordering the topics discussed in my literature review, I nevertheless found that categorisation is useful - up to a point - as an analytical tool. I subsequently however found it necessary to revise my original attempt, as shown in the following matrices (Figs 3 and 4). I initially devised the first matrix (shown in Fig 3), based upon both BM's and Susan D. Jones' methods of classifying surgical operations. I did this because the indications are that such distinctions affect the ways in which surgeons *think* about the operations they carry out, and therefore possibly their bodymapping strategies. For this reason, it would be useful to be able to categorise *individual* surgical procedures quite precisely as part of my analysis. I initially considered that all of the procedures discussed could potentially fit into one of four categories as shown in Fig 3.

	More tactile	Less tactile
Type 'A' surgery	1 Eg, spay, male neuter, or removal of a small mammary tumour.	2 Eg, surgery to remove a dew claw.
Type 'B' surgery	3 Eg, emergency spay in the case of pyometritis, or surgery for gastric torsion	4 Eg, surgery to repair a broken limb

Fig 3: A preliminary matrix for classifying individual surgical operations, based upon information provided by two veterinary surgeons (examples of surgery given in boxes).

A possible snag with this as a means of categorisation however (which incidentally only became obvious once I tried to actually 'use' this matrix as a tool for classifying individual operations), is that there are a number of variations that can be said to exist in relation to what constitutes an 'emergency'. Currently popular UK television documentaries about veterinary surgeons and veterinary practice[2] quite frequently feature cases that seem to accord quite precisely with BM's second category (Type B surgery), where animals present requiring immediate treatment (often involving surgery) in order to save their lives, for example due to injuries sustained in accidents. This mirrors to a certain extent popular *fictional* TV dramas about hospitals and medics[3]. We could give this 'first order' type of emergency a more specific label of its own. Let us call it a 'Type B1 emergency'. However, such cases are comparatively rare; I have never actually witnessed one first hand, either during 'official' fieldwork periods, or at any other time, although I have heard verbal reports from respondents and others about these 'interesting' cases. I *have* frequently observed situations where animals present with serious, potentially crippling (though not immediately life-threatening) injuries, but is this quite what BM meant by 'emergency'? In these 'second order' emergency situations, once appropriate first aid measures have been carried out, time can usually be taken to decide on the best course of action, which may include referral. Let us call these 'Type B2 emergencies'.

A further difficulty in relation to 'emergencies' is that such situations do not always arise (or at least they are not necessarily recognised as such) *prior* to surgery. Unexpected complications can manifest themselves at any time, for example during the course of the operation itself, or after its completion. This third type of emergency' can occur quite unexpectedly, even in cases where the animal concerned has undergone extensive pre-operative investigations, and where there was no indication beforehand that difficulties would arise. Such a procedure could therefore quite conceivably start out as a Type A case according to BM's classification, but change into a Type B one part way through, which would cause obvious difficulties in relation to the matrix. Let us call this a 'Type B3 emergency'. Thus 'emergencies' too, are subject to classification!

Each of these different situations would presumably demand from surgeons a slightly different response. It might be useful therefore, if 'emergency' situations which arise in relation to surgery could be categorised more precisely. I have therefore modified the matrix as previously shown in Fig 3 in respect of this, and this modification is shown in Fig 4 below:

	Type A	Type B1	Type B2	Type B3
More tactile	1 Eg, Spay, male neuter, etc	2 Eg, emergency spay in the case of pyometritis etc	3 Eg, Surgery for some types of cancer	4 Eg, haemorr -hage during oper- ation
Less tactile	5 Eg, removal of dew claw	6	7 Eg, cruciate repair	8

Fig 4: A revised matrix for classifying surgical operations, with some examples given.

All of the procedures discussed in this chapter and the next will fit quite precisely into one or other of the boxes in this revised Fig 4 matrix. The first and second examples to be discussed here will thus fit into Box 1, as shown in Fig 5 below. The third operation too, started out as a routine Box 1 operation, but due to anatomical abnormalities, unforeseen difficulties were encountered. It can therefore be reclassified as a Box 4 situation. Of course, it is quite conceivable that there are other surgical operations which would not fit easily into *this* matrix either, although it is quite satisfactory for our purposes here. Such is the nature of classification! We will revisit the classification of operations, and the matrices in chapters 9 and 10, though it is clear that this is not a straightforward matter.

Bowker and Star (1999) found moreover that this uncertainty is a feature of 'medical' classification more generally (even 'official' classifications such as the International Classification of Diseases as used by the WHO), rather than one that is peculiar to my own 'unofficial' attempts here. They described the ICD as a 'pragmatic' classification, in that it is evolving, and needs to allow for future developments and new discoveries (p.68-69). 'Pragmatic' presumably, in the same sort of way as my own modest, but evolving attempt!

	Type A	Type B1	Type B2	Type B3
More tactile	1 XX* Eg, Spay, male neuter, etc	2 Eg, emergency spay in the case of pyometritis etc	3 Eg, Surgery for some types of cancer	4 X~ Eg, haemorr -hage during surgery
Less tactile	5 Eg, removal of dew claw	6	7 Eg, cruciate repair	8

Key: **XX*** = Operations 1 and 2 **X~** = Operation 3

Fig 5: Diagram to show classification of operations 1,2 and 3 within the revised matrix

It is time now to leave classification for a while, and think in more detail about the ovario-hysterectomy operation itself, and precisely what it involves.

8.2 Ovario-hysterectomy

Ovario-hysterectomy, or 'spaying', is a procedure that is routinely carried out upon female domestic cats and dogs, principally to avoid unwanted breeding, but also (more rarely) to prevent and treat certain serious diseases of the reproductive system. It involves the surgical removal of the ovaries, fallopian tubes and uterus, through an incision along the ventral midline (usual in bitches) or the flank (usual in cats). According to textbook accounts[4], this incision should extend (in bitches), from the umbilicus (navel) to the pubic symphysis, but as we will see, its actual length *in practice* is subject to some variation. In all of the operations discussed here, these conventional routes of entry were used. I have however observed instances where alternatives have been chosen, due either to the preference of the surgeon, or a complication in relation to a specific case. For example, the respondent BM whom we have already encountered, preferred to use the lateral route (ie, via the flank) for spaying both dogs and cats, and some surgeons likewise favour the ventral route for both species.

Once the incision is made, the cranial[5] part of the reproductive system, (the ovaries and fallopian tubes), are first located, then the ovarian ligaments which hold these organs tightly in place within the body, along with their associated major blood vessels are loosened by pulling, then clamped and ligated (tightly tied off with suture material or *ligatures* to avoid haemorrhage), prior to their excision. Then the lower, caudal end of the system (the uterus) is similarly located, clamped, and ligated before it is excised above the cervix. After this the wound is closed, and the operation is completed. See Fig 6 below which shows the canine female reproductive system

In general it takes an experienced surgeon about about fifteen minutes to spay a young cat and slightly longer for a bitch puppy. Some half-jokingly pride themselves upon how quickly they can carry out these routine procedures[6]. Less experienced surgeons however will take rather longer, and as we will see, even experienced ones take more time in the case of older animals, or in other situations which are for some reason complicated.

8.3 Preparing for surgery: The production of 'disciplined' animal-bodies and surgeon-bodies.

Before an animal can be spayed, or for that matter, undergo any surgical operation, it is necessary that certain, preparatory procedures are first carried out. Obviously, the animal requires to be anaesthetised, rendering it immobile and unable to feel pain. However, this is only one part of the preparatory process. Hirschauer (1991) claimed that, in order for (human) patients' bodies to be made operable, it is necessary that both they, and also the bodies of the surgeons

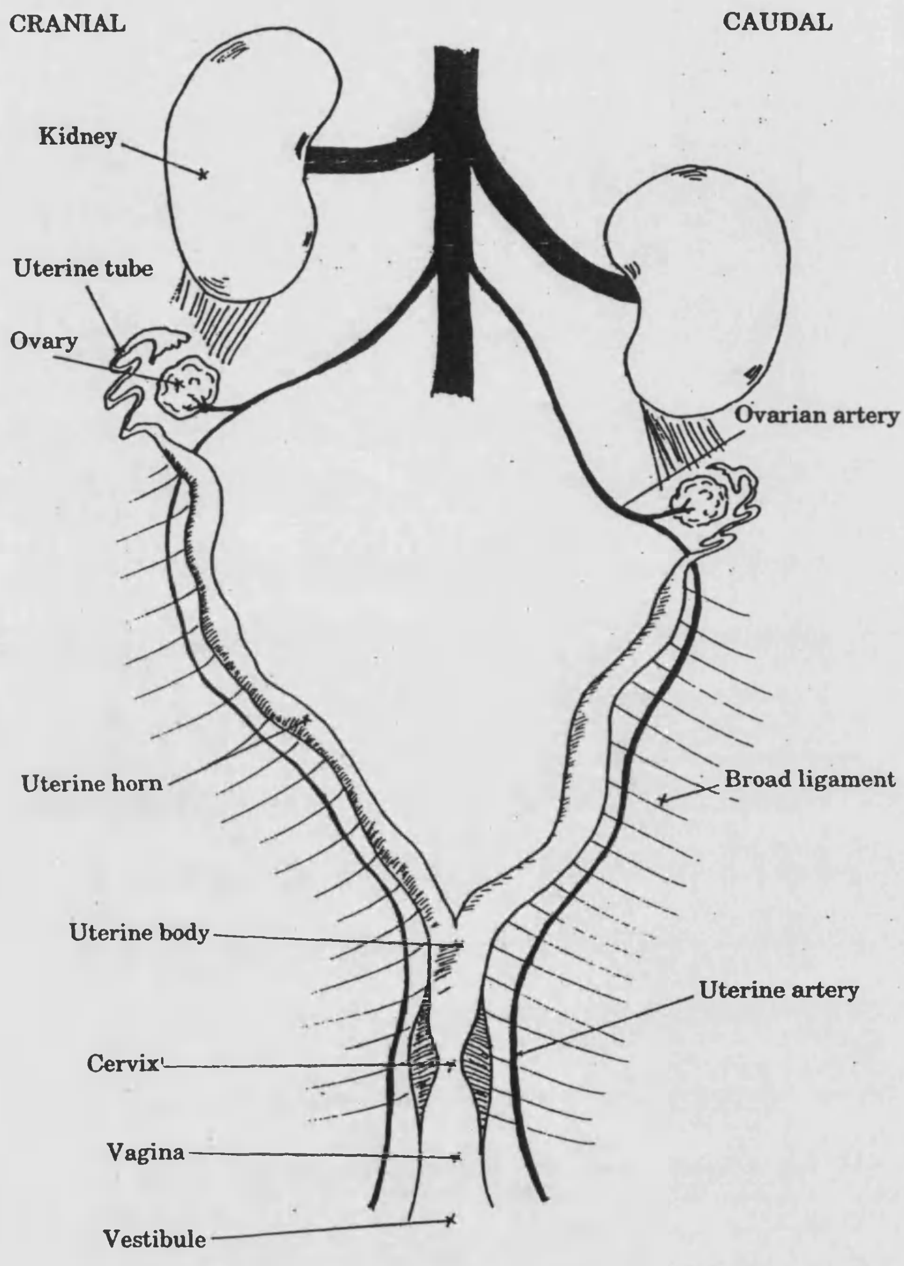


Fig 6: Diagram to show the reproductive system of the female canid (dorsal view). Reproduced from *An Introduction to Veterinary Anatomy and Physiology*, by A.R. Michell and P.E. Watkins (1989), with permission of BSAVA.

themselves, be 'disciplined' in certain ways. Some of the methods by which this is accomplished are outlined below.

Pre-operative preparatory procedures tend to be explained by surgeons in terms of their role in maintaining sterility and preventing infection. However, Katz (1981) and Hirschauer (1991) proposed a number of possible additional (or alternative) roles for these preparations. Of particular interest here, are Pearl Katz's proposal that these behaviours play a role in enabling action to be taken in situations of uncertainty, and Hirschauer's (1991, p.279) observation that anatomical visibility is 'created' (or constructed) by surgeons by means of these (and other) interventions. The self-preparation procedures undertaken by surgeons, such as scrubbing-up and gowning, and the pre-operative preparations of animal 'patients' are similar in many respects to those described by Katz and Hirschauer for 'human' surgery, (or at least, their 'textbook' descriptions are; as we will see, in actual practice things may be somewhat different).

Large differences were observed for instance, in the extent to which my veterinary surgeon respondents prepared *themselves* to operate. Hirschauer (1991) described in great detail the preparations that 'human' surgeons undertake, such as the ritualized hand washing movements involved in 'scrubbing up' (which are very different from those involved in everyday hand washing), and also the particular ways in which gowns, masks and gloves are put on, which again, are not at all the same as donning everyday clothing. These activities form part of a process which he referred to as 'the disciplining of the surgeon-body'. For Hirschauer, surgical operations provided a stage for encounters between two such 'disciplined bodies', that of the patient and the 'body of surgeons' themselves. In veterinary surgery however, it would appear that the amount of disciplining required both for surgeons' bodies (and as shown below, the patients' bodies also) is subject to some degree of variation.

In everyday practice for example, experienced surgeons rarely observed the strict 'scrubbing up' and 'gowning' rituals described in detail by Hirschauer for routine operations, and surgical masks and gloves were not consistently worn. Several of the surgeons observed wore the same clothing that they had previously worn to carry out consultations or other duties prior to surgery, perhaps with the addition of a plastic apron. Hand-washing too was in most cases much more perfunctory than the 'ritualised' scrubbing up movements described by Katz and Hirschauer *despite the fact that 'textbook' descriptions of the procedures are similar for veterinary surgery to its human counterpart.*

As far as preparation of the animal *patients* is concerned, the anaesthetised animal is placed upon the operating table in such a position that the operative site is most accessible and visible, its body held in place by items of equipment intended for this purpose. Some or all of the limbs may be tied to the operating table with cords, to keep them out of the way, and also to help keep the skin taut, (the skin of dogs and cats, particularly young ones, tends to be looser and more mobile than that of humans). This precaution ensures that the incision is not inadvertently made in the wrong place due to this mobility. Such measures assist in the surgeon's ability to relate the *internal* anatomy to the *external.* In addition, operating tables may be raised or lowered, and also tilted to allow better access and visibility. I have termed these **primary enhancement procedures.**

In the next stage, the entire body of the anaesthetised patient is customarily covered with cloths, or 'drapes', except for the immediate area where the incision is to be made. These drapes normally take the form of rectangular pieces of fabric joined with towel clips to effectively create a small 'window' through which the surgeon will operate. In animal patients, the incision site is shaved, which has the effect of further *demarcating* it from the remainder of the body. The site may be further *marked* by painting it with antiseptic, or even drawing the line of the intended incision. I have termed these **reduction** procedures, since their result is that the field of view, and thus the area of concern, is effectively reduced by their application.

I have adapted these terms from Gooding's (1996a p.80-95) description (and depiction) of how representations in science develop by a process of *dimensional enhancement.* This process involves first of all the reduction of an observed phenomenon in the world to a 2D representation. The resulting image is then enhanced by the addition of dimensions, to create first of all a 3D structure and finally (where causal explanations are sought) a 4D real-time process model. The result is a complex mental model that can then be applied to new phenomena. This application involves in its turn the removal of dimensions, in order to generate new representations, or to disseminate observations in the form, say, of printed diagrams or photographs in scientific papers.

The processes discussed here are similar in two important ways. Firstly, that a complex whole is reduced to a less complex part which is the subject of the operation (in this case a surgical operation). The gross anatomy is thus effectively 'reduced' by the means described, to the immediate area of concern. Rather than initial *reduction* however, primary *enhancement* is required (by means of positioning) so that the abdomen (in the case of ovario-hysterectomy) for example becomes the most apparent anatomical area. Only by means of this *enhancement,* is the body effectively *reduced* to the most salient part. This abdomen is in turn reduced to the smaller area (by means of shaving, draping etc) which will become the incision site. Once the incision is made, the mass of internal organs may in turn be 'reduced' by various means, to only those of relevance to the procedure in hand.

Thus the body is subjected to continuous and alternating processes of enhancement and reduction. Hirschauer (1991 p.299) chose a different metaphor, referring to these pre-operative procedures in terms of a process of 'targeting' which is later continued by 'instrumental means'. After the operation is closed (literally, with the closing of the incision by suture, as well as closure being achieved in a more cerebral sense at the conclusion of the operation), the instruments of reduction and enhancement are removed one by one, and the 'whole' body restored. Once again, Hirschauer (1991) chose a military metaphor for this latter process, that of 'retreat'.

A second similarity is that complex process models of particular surgical operation are constructed, and these can later be 'applied' to others (one respondent referred specifically to *'a sort of library of cases'* that she had built up). They may also lead to the dissemination of images and verbal descriptions of them, for example in the books and journal articles that surgeons circulate and use. These similarities may indicate that the phenomenon to which Professor Gooding referred is not necessarily limited to innovative scientific discovery, but occurs also in more commonplace activities. This idea will be revisited in the final chapter.

Of major interest here is the extent to which these enhancement and reduction practices varied between surgeons and between operations, and the identification of factors which may help to influence this variation. I examine firstly the roles that pre-operative procedures may play *apart* from the commonly stated one of infection prevention. Secondly, I show how vets use what one respondent called 'visual aids' in order to map the internal body, to varying extents depending upon their previous personal experience of carrying out the procedure. Thirdly I show an instance of how one experienced individual proceeded in a situation of uncertainty, in relation to variations that occur in the body's organs. I do so through detailed analyses of three ovario-hysterectomy operations, carried out by two different veterinary surgeons. I am also informed by additional comments elicited from two others via interviews. As I pointed out in chapter 6 however, these analyses are also based around many additional hours of observation, of both these and other soft tissue procedures.

In contrast to the cases from 'human' surgery described by Katz and Hirschauer (which invariably followed the 'textbook' pattern above), I have observed a great deal of variation in veterinary practice, in the extent to which pre-operative preparations of both patient and surgeon were carried out, in the performance of routine operations such as ovario-hysterectomy. Moreover, as a general rule, such variations seemed to occur in line with the amount of actual experience that surgeons had accrued in carrying out this procedure. A training video produced for student veterinary surgeons and nurses (GDBA 1996), and the principal textbook used by trainee veterinary nurses (Lane and Cooper 1994), both show pre-operative preparations carried out in line with what I have termed the 'idealised' model similar to that used for 'human' surgery, represented in Fig 7. In observations of actual veterinary surgical practice however, it tended to be the case that, the more experienced the surgeon, the less time and trouble he or she would take over these preparations. Conversely, recently qualified vets performed the procedures in a way much closer to this idealised, 'textbook' method.

With experienced surgeons, draping was frequently observed to be somewhat haphazard. I observed its total omission in some soft-tissue operations (though not in the case of spays). I also saw on at least one occasion, the same drapes used for successive spay patients, rather than a newly sterile one each time. The operating table itself, instead of being thoroughly sterilised to prevent possible cross-infection, was often given the merest cursory wipe between patients. These last two points rather challenge the 'received wisdom' that these pre-operative preparations are essential for purposes of infection prevention.

When questioned about these procedures, respondents nearly always explained them in such terms. I would argue however that on occasion, some of the measures *as they were actually carried out* may have *increased* rather than *decreased* the risk of post-operative infection caused by the invasion of the wound by micro-organisms, and that, either in addition to or instead of this professed purpose, they are used for quite another reason. Despite the apparent skimping of these avowedly essential anti-infection procedures, I have seen little evidence of post-operative infection. Any problems that did occur tended rather to be related to either anaesthesia, to the abnormal or unfamiliar anatomy of individual animals, or to disruption of sutures. According to Katz (1981 pp.135-136), these purportedly infection-preventing measures were not in any case particularly effective in containing the risk of post-operative infection in human patients.

Interestingly, I observed that the use of instrumentation too, varied along the same lines. Considerably fewer clamps, retractors and so on were used by more experienced surgeons for routine surgery, than by those with less experience. Fig 7 below shows what I have called an 'idealised model' of pre-operative preparations, adapted from information in a textbook for trainee veterinary nurses (Lane and Cooper 1994), and a training video aimed at student veterinary surgeons and nurses (GDBA 1996), as they could be applied to these soft-tissue operations.

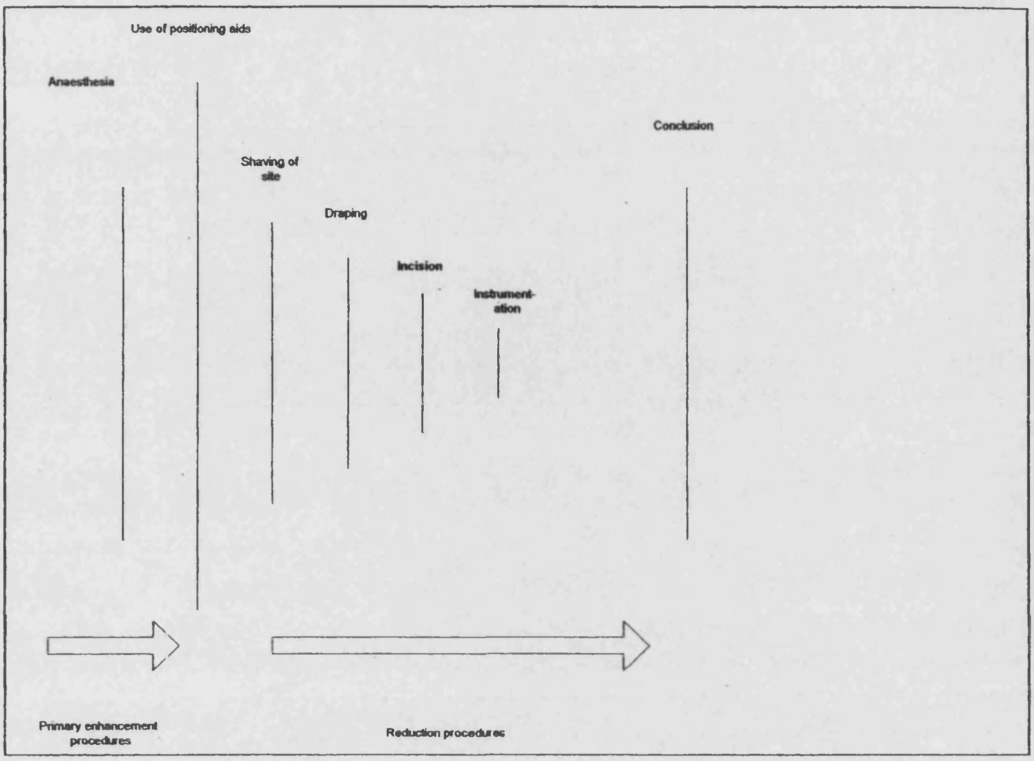


Fig 7: Diagram to show an 'idealised' model of primary enhancement and reduction procedures used prior to soft tissue surgery.

This purpose of this diagram is to illustrate the use of primary enhancement and reduction procedures in an ovario-hysterectomy operation, (from the beginning, taken to be the induction of anaesthesia, to the conclusion where the reproductive system is successfully removed, and the wound closed), as performed in the accepted 'textbook' manner. As discussed previously, this model is somewhat 'idealised' in routine veterinary surgical practice, (in that it is taught to novices, but not always adhered to by experienced practitioners, hence the title that I have given to the diagram). The lines on the left of the diagram are intended to show the 'Primary Enhancement' procedures relating to positioning, which effectively increase or expand the field of view of the site where the operation is to be performed. Towards the right of the diagram, this field of view is shown to be gradually diminished (indicated by the shortening length of the vertical lines), by 'Reduction' procedures which visually 'Reduce' the patient's body to the portion relevant to a specific surgical procedure (in this case, the reproductive system and the external area via which it is to be accessed).

I next move on to analyse three instances of ovario-hysterectomy, one of which (operation 1) was carried out by a recently qualified surgeon, and the other two (operations 2 and 3) by another who had amassed a considerable amount of experience. I use observations of these three operations, plus contributions from interviews with two other surgeons, to illustrate first of all a proposed alternative role that pre-operative procedures may play, apart from the stated one of infection prevention; that of providing 'visual aids' to help map the body. Secondly I show how vets tended to use these aids to varying extents according to their previous experience of the procedure. Thirdly, I describe an instance in which one experienced individual was confronted with a situation of uncertainty in relation to variations that occur in the body's organs, and show the strategy that he used to deal with this

8.4 Operation 1: Using 'visual aids'

The following is an extract from my field notes, quoted verbatim, though annotated as necessary:

26 February 1999:
James operating; Australian, young a bit nervous (of being observed). .Doesn't talk much, but will answer questions. Felt slightly reluctant to ask too many, for fear of unduly distracting him. Tanya, vet nurse, more forthcoming

Bitch spay / umbilical hernia repair, young Jack Russell bitch.
Bitch anaesthetised, then nurse shaved ventral area, swabbed with antiseptic solution. Animal placed in dorsal recumbency[7] in a special 'cradle' (or support), hind legs tied to operating table to allow access to operative site. Patient then carefully draped, leaving only operative site visible. James scrubbing up fastidiously whilst all this is happening, put on gown, gloves, mask, cap. Tanya asked to help with fastenings - difficult, since she was occupied already with preparing the patient.

Incision using scalpel, scissors, forceps, umbilicus to pubic symphysis. First exposes hernia (small), pushes back Isolates and ligates right uterine horn, fallopian tube, ovary, excises cranially[8]. *Nurse offers to tilt table 'to get rid of that spleen' which is partially obscuring the reproductive organs. Offer accepted, does so. Spleen slides upwards away from operative site. At this point, various tissues, skin layers etc held apart by forceps, retractors, etc. Wound held open. Vet inserts gauze into wound, isolating. Explains when asked that it is to 'hold the intestines down, more a visual aid than anything else'. Ligates left hand part of repro system, detaches from blood vessels etc cranially.*

James then moves gauze, using it to effectively close wound, uterine horns etc held by instruments outside incision, still attached caudally[9]. *Uterine body then clamped, tied off excised Gauze pad then removed. Prepares to close incision, inner layers first. Tissue held clear of internal organs by means of forceps.. Closes upper layers, cleans seeping blood off area around wound in order to see better. Wound finally closed, legs untied, clips and drapes removed'*

This procedure is similar to that which follows (operation 2), in that it is a category 1 operation as related to the revised matrix shown in Fig 4. However, whilst it is similar in many respects (in that it proceeds in an uncomplicated fashion, no difficulties being encountered with the anaesthetic, the instrumentation or the anatomy), it will become clear that there are nevertheless differences also between the two procedures. For example, operation 1 was considerably longer in duration than operation 2, and as the above excerpt clearly shows, the pre-operative sterility procedures, as related to both the animal's body and the surgeon's body (Hirschauer 1991) were carried out in a particularly thorough 'textbook' manner here, although there was nothing at all to suggest that this case posed a particularly high risk with regard to infection, or was other than routine in every respect.

Such thoroughness on James' part in fact caused a small problem, for unlike 'human' surgeons, vets do not usually have large teams of nurses and junior surgeons to assist them. As a rule there is just one surgeon who carries out the actual operation, and one assisting nurse, who is responsible for preparing the patient, monitoring the anaesthetic and performing any other tasks required. This was the case here. However, one assistant can only do one thing at a time, and there was an awkward moment when Tanya was asked to assist James with his gown whilst she was already occupied with preparing the animal for surgery. She had to temporarily abandon this task in order to tie the gown and help James to put on his 'sterile' gloves. This would clearly have compromised the sterility of the gloves and thus that of James, since Tanya had not previously scrubbed up herself, and had in addition been engaged in performing 'dirty' tasks such as shaving the operative site.

These elaborate preparations may be due to the fact that James had completed his training only relatively recently, and aspects of it were still fresh in his mind. Related to this, it could indicate that, as a 'competent' performer who had yet to achieve a significant measure of 'proficiency' or 'expertise' in relation to this procedure, he still had to remember 'the rules' for carrying it out (Dreyfus 1986; Benner 1984). However, there appears to be more to this than mere 'rule following' behaviour, since in addition to the standard 'primary enhancement and reduction procedures' of positioning, shaving, draping and so forth, James added a **'further enhancement procedure'** of his own. He used swabs to cover and thereby to some extent conceal those internal organs that he was not directly concerned with for the purposes of this operation. This creative, constructive act, shown illustrated in Fig 8 below, draws an interesting parallel with the ways in which illustrations in anatomical atlases are constructed, where organs which are not 'part' of the particular system that is the subject of the illustration *are not shown in the illustration, even if this requires that they are dissected out from the cadaver prior to the photographs being taken*[10].

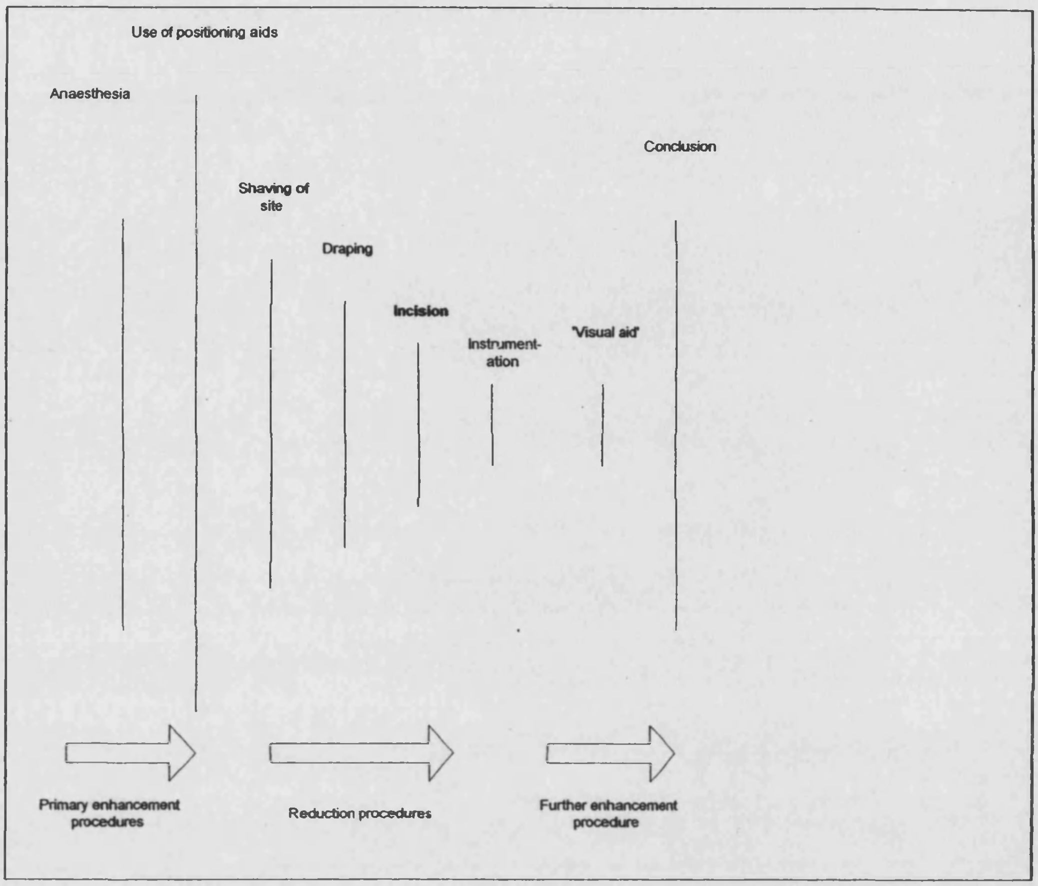


Fig 8: Diagram to show James' addition of a 'further enhancement procedure' (shown towards the right of the diagram), in this case, the covering of organs unrelated to the procedure in hand (termed by respondent as a 'visual aid').

Hirschauer (1991) referred to ways in which actual bodies are made to resemble (and thus 'merge with') the pictures in anatomical atlases from which 'they' are learned, and this appears to be related to what James was doing *in* this instance. When I asked him about this use of swabs, James replied that it was *'more a visual aid than anything else'*. It appears that it may have been one of his own devising. I have since asked several vets whether they have ever done this, or seen anyone else doing it, maybe in a practical class at university. None had. One informant, JH, replied particularly vehemently to the contrary:

JH: *'No, not gauze, I've never heard of that. I'd be concerned that using gauze swabs in that way would cause the wound to dry out too much, that it might be harmful, cause adhesions. Anyway, once you've got the uterus exteriorised, you can just see it... can't you?'*

It might be useful to examine other examples at this point, in order to effect a comparison between James' approach to this task, and that of others.

8.5 'Bodymapping for beginners': learning the trade

Experienced vet JH spoke here about learning new procedures:

JH: *'You have to start with the basic anatomy, and what the procedure actually is, like a textbook description of how its done and so on. You need to watch a procedure 2 or 3 times; there are people who will dive straight in, but I would always want to watch someone else do at least one..., then do it. Maybe if you're lucky you can assist first...'*

When asked specifically about spays, she added:

JH: *'You need to have watched, felt things like the tension on the ovarian ligaments when assisting. And when you do the first one, its good to have someone there to advise if you get stuck..'*

JH's insistence on the importance of 'feeling' as well as 'watching' suggests the importance of eyes *and* hands in performing these 'tactile' procedures. Her comment also shows the importance of social, or enculturational aspects of learning, as well as the 'algorithmic' ones. It is probably impossible to describe exactly in a textbook account (or even to represent visually in some other way, for example by drawing) exactly how the ovarian ligaments *feel*, even though it is perfectly feasible to describe the mechanics of the procedure verbally, and to draw the structure and paths of the ligaments themselves. This latter point calls to mind Collins' (1974) account of scientists' inability to build a working laser of a certain type without recourse to personal interaction with a community of laser builders, and may help explain JH's emphasis on the importance to her of 'watching' and 'assisting' another surgeon prior to carrying out an unfamiliar procedure herself.

Another respondent (RH) reported how, many years previously, shortly after he had started his first job, he had been shown by his practice principal how to judge exactly where to make the incision for a cat spay by drawing an imaginary triangle from the hip to the top of the femur. The third point of the triangle is where the incision is made. I asked JH if she was familiar with this, or any other rules for relating the inside of the body to aspects of it that can be seen or palpated externally, and if such rules form part of the formal surgical education that vets undergo, or alternatively whether they are passed on more informally between colleagues. JH replied:

JH: *'I haven't heard that one, but there are others; you don't use the hip, you feel the top of the tuber ischiae, and you use the distance between the joints in your thumb to just judge the right place'.*

Her answer *'there are others'*, plus the necessarily approximate technique described, of using the distance between the joints in one's thumb (such a distance being variable presumably, with the varying size of practitioners' thumbs), to judge the point of entry seemed to indicate that such heuristics are part of the informal body of knowledge of veterinary surgery, rather than being inscribed in formal terms. Of course, these are not absolute categories; 'formal' textbook knowledge must after all contain implicit, informal elements, or it would not be possible to apply it in actual practice. Likewise, informal' knowledge (or at least some elements of it) may be inscribed in formal terms, for example by writing it down (Pinch et al 1996).

Whilst she was speaking, JH was looking intently at the surface of the table, and making movements upon a very small area of it with the point of a pencil. She continued:

JH: *'You need to remember how moveable the skin is, and that what is underneath it doesn't necessarily move. I remember being taught, I don't remember whether it was at college or in practice, you have to pull the legs back and tie them to the table to keep the skin taut, stop it from moving about.'*

JH was reminiscing, in part, about her training days. However, 'book' learning merges over time with one's own experience knowledge (presumably in a similar sort of way to that in which actual bodies come to merge with anatomical pictures in the course of surgical operations), and it becomes therefore difficult to see or to remember where the boundaries between formal and informal knowledge lie. Her movements with the pencil point upon the surface of the desk as she spoke seemed to indicate the difficulty of talking, or even thinking about these matters outside of actually performing them. Knowledge may be inscribed in skilled practice itself.

Formal and informal training and learning do not cease upon gaining initial qualifications, or *license* to practise. Learning new techniques is after all a continuous process, even for those persons who already have some degree of 'expertise' like JH. It is important to take on board that 'expertise' is specific, to specific procedures and contexts. Certain elements of it may be transferable directly (Pinch, Collins and Carbone 1996). However, there is scope for considerable further research in order to determine more precisely the nature of these elements.

JH went on to describe a specialist training course in which she had recently participated:

JH: *'You can use mock-ups for some things, like I went on a course the other week on laparoscopic techniques for horses, like for colics and so on. We practised using the endoscope with a plastic box with holes cut in it to represent the horse's abdomen; looking around with the endoscope, and practising manipulating instruments. Sometimes you can practise new techniques on dead animals...'*

In common with other professionals, such as 'human' medics, nurses and teachers, veterinary surgeons are required to participate in continuing professional development (CPD) programmes. This becomes especially important in respect of technology such as endoscopes whose use is relatively new in general veterinary medicine. JH's account mirrors (though obviously in a rather less sophisticated way), the use of virtual reality simulators to teach complex new procedures to surgeons in 'human' medicine, thus avoiding the need to practice on actual patients (Taffinder 2000)[11]. This is an example of a *formal* learning situation; outside of this, considerable *informal* learning and instruction goes on. Events such as conferences, local association meetings and other social gatherings provide the opportunity for interaction, and therefore also opportunities for knowledge to be passed between colleagues. Other 'informal' learning goes on inside veterinary practices themselves. Accounts of such learning are shown in chapter 9.

In the following short excerpt, I refer to the reported experiences of a novice surgeon. Richard, a fourth year veterinary student was on placement from university during one of my observation periods, 'seeing practice' (as it is termed) with one of my collaborators. He described how, although he had not 'done anatomy' at college for two years, he still 'practised' on his family's pet dog at home, identifying the anatomical structures that can be palpated from the exterior, and also the various incision sites for particular operations. He described how he and his fellow students used this method as an aid to revision for examinations and practical assessments, often in conjunction with a textbook. In my own teaching, of anatomy to veterinary nurses, I have also used live animals as 'visual aids' (although 'visual' is probably an inadequate term to describe something which is both 'visual' and 'tactile' in this way), for example encouraging the students to identify the individual bones in a diagram of the skeleton by gently *feeling* those of a tame live animal.

Discussing anatomy, Richard outlined his own problem as a beginner with far less experience than James:

Richard: *'It looks totally different in books... when you actually come to an op, it's hard to tell what is what, even though I can actually sit and draw the paths of the major blood vessels and so on...'*

Richard's remarks illustrate the initial difficulty that novices experience in relating their 'book learning' to actual practice; the crucial differences that exist between 'knowing how' and 'knowing that' (Polanyi 1958). Hirschauer (1991) referred to this question of how surgeons *learn* anatomy, and how patients' bodies are related to, (or become merged with), anatomical representations of it. It would appear that they learn the *discipline* of anatomy *by rote,* from books, pictures and other representations of it. Actual bodies however are related to such representations *in practice,* perhaps by similar methods to the simple one described above. It would seem that it is necessary that patients' (and surgeons) bodies themselves *be disciplined* (Hirschauer 1991) in order to achieve this. Richard's comments, and also those of JH indicate that much of a surgeon's skills are acquired outside of what counts as 'formal' training, even through the actual practice of operating itself.

8.6 Operation 2: From novice to expert

It may be useful at this point to consider the procedure as it is carried out by a practitioner who is something of an 'expert', (this is my designation, not his own). RH is a veterinary surgeon '*of some thirty years experience*' (on his own estimation). I was able to watch RH perform this operation on some twenty occasions, and it is probably fair to say that this procedure, together with male neutering and dental work made up the bulk of the surgical operations that he carried out during the observation period. As a rule, RH's spay operations were of very short duration, as shown in the following extract:

Bitch spay, French bulldog. Anaesthetic by injection, endotracheal tube also inserted due to breathing difficulties that brachycephalic[12] *breeds often have... Shaved forelimb. Vein a bit harder to find than normal, as skin black*[13] *, but no problem. Placed in dorsal recumbency, in cradle, shaved, swabbed, draped, one hindlimb tied to table. Incision: scalpel first, through skin, then scissors 'There's that spleen again'. RH again pointed out danger of nicking spleen if not careful. Found uterine horn straight away, pulled to break ligament, clamped, ligated, excised cranial to ovary, repeat other side. Then body of the uterus, clamped, ligated cranial to cervix, excised. Stitched two layers. Very quick. RH: '15 minutes, that's not bad'.*

For RH, pre-operative procedures, as related to both the patient and to his own person, were fairly perfunctory for spay and other routine operations. Apart from this, other major differences in his performance as compared to that of James related to the amount of time taken to complete the procedure (much quicker), the number and type of instruments used (fewer), and the size of the incision (smaller). RH habitually used an incision barely half the size of the one made by

James, and incidentally recommended in the training video. A consequence of this is a smaller wound, from which the animal would recover far more quickly, and in addition, fewer stitches to cause problems in the immediate post operative period.

Instead of the usual rectangular drapes joined with towel clips, which effectively close off the field of view except for the rectangular 'window' through which the operation takes place, RH used what he called 'spay cloths', squares or rectangles of green cotton fabric of varying sizes, with a small slit carefully cut out and hemmed round in the centre. RH's field of view was therefore correspondingly much smaller than James's, (limited that is to what could be seen through the slit in the fabric), presumably to account for his smaller incision. It was so small in fact, that I seriously doubt whether the internal organs were rendered anything like fully visible at all, though this seemed to matter little to RH. The following excerpt (taken from observation notes relating to a cat spay) illustrates this quite nicely:

RH: *'...see, that's the ovaries... if you can find them, there, the rest of it is easy...'*
Self: *'But you can't see. How do you know if you are fishing out the right bit? I mean, you could have intestines or something..'*
RH: *But you can see... it looks different.., you just go in between the two.... This fat is very solid at the top, and the other is very sort of loose, omental fat at the bottom. You just go in between these two.... and it looks different, it's got very big blood vessels and very thin.., and that looks completely different*[14]*...*

RH was missing my point entirely here. I know very well the difference between ovarian ligaments and intestines - once I see them - but I *do not know* if I would see them through a very small cut (in length not much more than the diameter of a 2p coin) in the side of a cat. I would surmise that RH worked as much by memory and by touch sense as by vision. Although he insisted that he could 'see', I am not at all sure that he meant this in any literal sense relating to visual perception. The phrase 'I see' can after all mean far more than this. Also, he often alluded to the use of other senses; for example the 'feel' of the tension of the ovarian ligaments, and the 'click' sound that you listen for in order to ascertain whether this ligament has broken as required. It would seem that, for RH, perceptual data as relating to spay operations were in some respects merged together, and merged also with other information encoded in memory.

RH generally used 'spay cloths' of different sizes for cats and for dogs, although sometimes he ran out of one sort, and indiscriminately used the other. On one occasion, he used the same cloth for a number of spays carried out on both cats and dogs, one after the other. When asked about the importance of drapes, RH was quite insistent that they are essential *'to keep hair out of the wound and prevent infection'*. He appeared not to notice however that on this particular occasion, the operation was almost completed before the nurse had produced the requested cloth.

This differential use of what (after Gooding 1996a)I have termed 'enhancement and reduction procedures' by the relatively inexperienced vet, and by an experienced surgeon seems to indicate that these procedures may play some role in mediating uncertainty. James appeared to need to use visual aids in order to see the various internal organs 'as' intestines, ovarian ligaments and uterus (Miller 1996). Whilst RH ostensibly paid little attention to this 'problem' of identifying and differentiating individual organs, (which was generally so unproblematic for him that he, despite his willingness to discuss any aspect of his work, or for that matter anything else, seemed to find it difficult to talk much about this topic at all), he nevertheless placed great emphasis upon the possible hazards that the operation might hold for the animal.

For example, he 'saw that' (Miller 1996) there was a need to avoid inadvertently nicking the spleen with a sharp instrument. The spleen is a large, red organ full of blood, which is responsible among other things for the manufacture of many of the types of blood cells present in the circulation. Such an accident might well prove fatal to the animal patient, since it would be very difficult, perhaps impossible to arrest a haemorrhage from this organ during surgery. On several occasions he (and also other respondents) mentioned this concern. RH avoided the use of the scalpel as much as possible for this procedure on account of this perceived risk, preferring to use scissors and / or his fingers (as he termed it 'blunt dissection'). In James' case however, it had apparently been necessary for the (experienced) nurse to gently remind him of this hazard by offering to tilt the table *'to get rid of that spleen'*.

Another important concern with this procedure is the need to check the stumps of the tied off ovarian ligaments (and their associated blood vessels) for bleeding, and the security of the ligature:

RH: *'Always need to check the stumps, make sure they're not bleeding before I let go, because once I let them go they disappear right up around the kidneys, I wouldn't find them again. Some vets will actually tag them before they let them go...'*

RH was seemingly able to concentrate his attention upon the real hazards entailed in this routine procedure, because he no longer needed to devote mental resources to imposing sense and order upon the internal anatomy during this surgery. For RH, it would appear that this had passed into the realms of the tacit. His response to my question about the possibility of mistaking lengths of intestine for ovarian ligaments indicated this; it was not an issue, so not worthy of mention, or presumably even thinking about. James, in contrast, seemed to have to bring virtually all of his resources to bear upon this problem of organ location and identification, apparently leaving little available for other considerations. The respondent JH spoke of the way in which she had built up a sort of 'personal library' of cases over time. Presumably, the more comprehensive is a particular section in one's personal library, the less attention need be paid to elementary texts!

The 'enhancement and reduction' procedures described in the examples above, appear to be one means by which bodymapping is accomplished, and it would seem that, the less experienced the surgeon, the more necessary (and the more elaborate) are these procedures. Another potential 'aid' is the use of language. Pinch *et al* (1996) showed how their surgeon respondents *talked* their way through the processes of identifying various organs and tissues in situations of uncertainty. I too have observed this, and describe such a situation in the account of operation 3 below. A problem which may precipitate this behaviour relates to variations that can occur in the size, and even the position of internal organs. As JH put it:

JH: *'There is a lot of variation in dogs, like the different breeds and sizes. If you do a German Shepherd the first time, it won't be much like the Yorkshire terrier* *you get next! And there's a lot of variation in cats, too. The size of the uterus will vary, it might be in season and so forth...'*

And RH:

RH: 'In dogs there's a huge variation; it depends on the size or breed of the dog and the fatness of the dog. This one, because she's young and quite skinny, they're quite small'.

Apart from these 'normal', or expected variations that occur along the lines of breed, size and reproductive cycles, are other, rarer ones, related to abnormalities in individual anatomy, as shown in the next section.

8.7 Operation 3: When things go wrong - 'words speak louder than actions', or the use of verbalisation in making sense of perceptual experiences

Skilled 'operators' in this sense, as in others, often seem able to perform a familiar procedure almost without thinking about it; the skill has passed into the realms of the tacit. Only when things do not go as expected, or the surgeon encounters something unfamiliar, does the skill regain visibility. RH habitually chatted about unrelated matters; his family, sport, films, music, TV programmes and other cases to give a few examples, as he daily performed these routine operations. He positively welcomed conversation and company whilst he was operating. He would chat to anyone present - myself, a veterinary student, the nurse, even (on one occasion) the owner of an animal upon which he was operating, about all sorts of topics. Off-task talk is of interest here because the indications are that no actual bodymapping is going on whilst surgeons are discussing other matters, or making casual social conversation. Only at certain points did RH appear to have to really concentrate upon the task in hand. The parts of the operation requiring particular focus of attention was the incision, then the location and ligation of the ovarian ligaments (as reported by the respondent). At these points, off-task talk would generally cease. This followed a pattern that was also observed when other experienced surgeons carried out the procedure'[15].

When the situation demanded it, RH immediately switched back to task. In the following exerpt, he was observed to cease off-task chat and switch to an alternative use of language, as a sort of personal 'bodymapping aid'. Present on this occasion were RH himself, Ella (an overseas veterinary student), a veterinary nurse (VN) and myself. I have highlighted the bodymapping language in bold type.

GSD[16] spay with mammary tumour removal. Intravenous induction; animal difficult to restrain. Once induced[17], dorsal recumbency in cradle, hindlimbs tied to table. VN started to shave area, and dog started to wake up, 'went really light'.[18] RH gave more anaesthetic, and intubated[19]. Ella swabbed area with yellow antiseptic... Incision, scalpel, then tore with fingers (RH couldn't find scissors, and does so worry about 'that spleen'). Fat animal, RH felt deep inside for ovaries ***'very deep down near the back'.*** *Feeling.* ***'Can't get the ovaries out.... very tight....'*** *(enlarged incision slightly)...* ***'Is that a lump there... or just fat'?*** *RH finds ovary, ligates. Chatting about the next case at this point. Exteriorized one side of repro system, cleaning site with a swab.*

Back on task again, other ovary also difficult to get out. ***'Try and get this other ovary out, won 't come out.... very well...'***
VN.~ 'Is that because its so deep?'
RH: ***'Yeah, and its so tight.... doesn't feel very good... doesn't feel right..., attached in an odd way; I'll do the body*** *(of the uterus)* ***and then go back to it....***
Clamped body, ligated. Lots of clamps in place, lots of bleeding leaky vessels, swabbing site.
RH: ***'Just this nasty ovary now... afraid to pull too much, in case it tears off... oh goodness, it doesn't feel nice...***
VN: Does it have cancer or something?
RH: No I don 't think so, but ***its very friable underneath. Normally there's a distinct ligament that you can break.... that's alright I think I've got it*** *_(more swabbing)* ***'...big cyst on this ovary, but its a real big area altogether. Its a rather unusual shape.. try to tie it off without too much fat in it...when you've got too much fat, it tends to slip...*** *' (more clamps, more swabbing)* ***'better tie all this fat off as well..'***
Ella moves drape aside to enable RH to see better. He excises the repro system, separates from body. Sticks odd bits of fat back into the wound. Suturing ***'not bleeding, that's fine....'*** *Carried on suturing lower layers, then skin layer. Moved*

table to a higher position. Back hurts, long tense procedure. 'I like to do the op really low, and then the stitching higher. Its hard to get right in if its high'. Now suturing... Last stitch. Quite a long op, hard work, (RH needed to concentrate more than usual,~first time I've heard him 'bodymapping' out loud) Still doing it;

'Had a very odd ovary, very peculiar, thought it would bleed.... unless you open it all up this big, you can't do it all inside..., very cystic, no proper ligament....'

RH, who routinely chatted about varied (and often unrelated) topics during surgery, found it necessary to map the body almost in a similar sort of way to James on this occasion where a 'routine' operation revealed itself to be anything but. Some of RH's talk seemed to be in response to the questions of the veterinary nurse and the veterinary student who were also present, but bodymapping talk is not necessarily directed at another person. Hirschauer (1991) described how surgeons sometimes explain surgical problems to others present in order to develop their own thoughts, and referred to a German surgical textbook which expressly stated the usefulness of such 'thinking out loud'[20].

This particular procedure had started out as a 'routine' operation for which pre-operative examinations had been carried out (Type A surgery according to the respondent BM, fitting into Box 1 of the matrix in Fig 3). However, as it progressed, it became clear that it was in reality a Type B situation (Box 4 according to Fig 3). It is possible that RH may have had some prior misgivings about how this particular operation would proceed. He had often expressed anxiety about performing the operation (or indeed, any operation) upon fat animals such as the one in question, and had referred more than once to the fatness of this particular animal both prior to, and during the procedure.

RH's uncharacteristic verbal bodymapping behaviour was due (I would surmise) to the unfamiliar and ambiguous nature of the anatomy. Instead of relying upon 'visual aids', (it was too late to apply or reapply the visual enhancement and reduction procedures previously described - which had as usual been perfunctory in RH's case - since the problem occurred only once the operation was under way), he made use of language, bodymapping *talk*. Perhaps also, visual aids are not especially effective in instances such as this where the problem is to try to relate encountered 'abnormal' anatomy to the learned 'normal' anatomy of textbooks. In any event, RH *talked* his way through the procedure in this situation where he encountered an anatomical variation that was unfamiliar to him. He was apparently using language by way of a 'further enhancement procedure'.

There are parallels here also with the student Richard's painstaking comparisons of 'textbook anatomy' with the 'actual anatomy' of his pet dog, when revising for examinations. Hirschauer (1991 p.279) wrote of 'the relation of experience to representation', in the sense of 'how patients bodies come to embody the properties of anatomical pictures'. RH had by this point long ago lost any need to use *physical* images such as anatomical pictures (at least in relation to this particular procedure). He had *internalised* canine and feline reproductive anatomy, to such an extent that for most of the time, it seemed hardly worthy of mention. It had become part of the personal 'mental library' (as spoken of by JH), which is available for experienced practitioners to draw upon. What RH may have been doing though, was 'adding to' this library; merging this new variation with the *mental* anatomical representations available to him of reproductive anatomy, in the light of this new experience.

RH's verbal bodymapping ceased once initial problems were resolved (in locating the first ovary), when he reverted to his customary off-task chat. However, he returned to bodymapping talk again when further difficulties were encountered in finding and dealing with the second ovary. This switching between off- and on-task talk as occasion demanded it was observed on several occasions and in different respondents. Interestingly, these surgeons all had considerable experience in carrying out the procedures involved. Inexperienced respondents such as James used very little off-task language, and neither were they observed to 'bodymap' out loud. Obviously, so few observations cannot be generalised, but it would appear that for *these respondents* at least, language was more likely to be used as a bodymapping strategy by those who used correspondingly fewer *visual* aids. I have modelled RH's use of language alongside visual enhancement and reduction procedures in Fig 9 below.

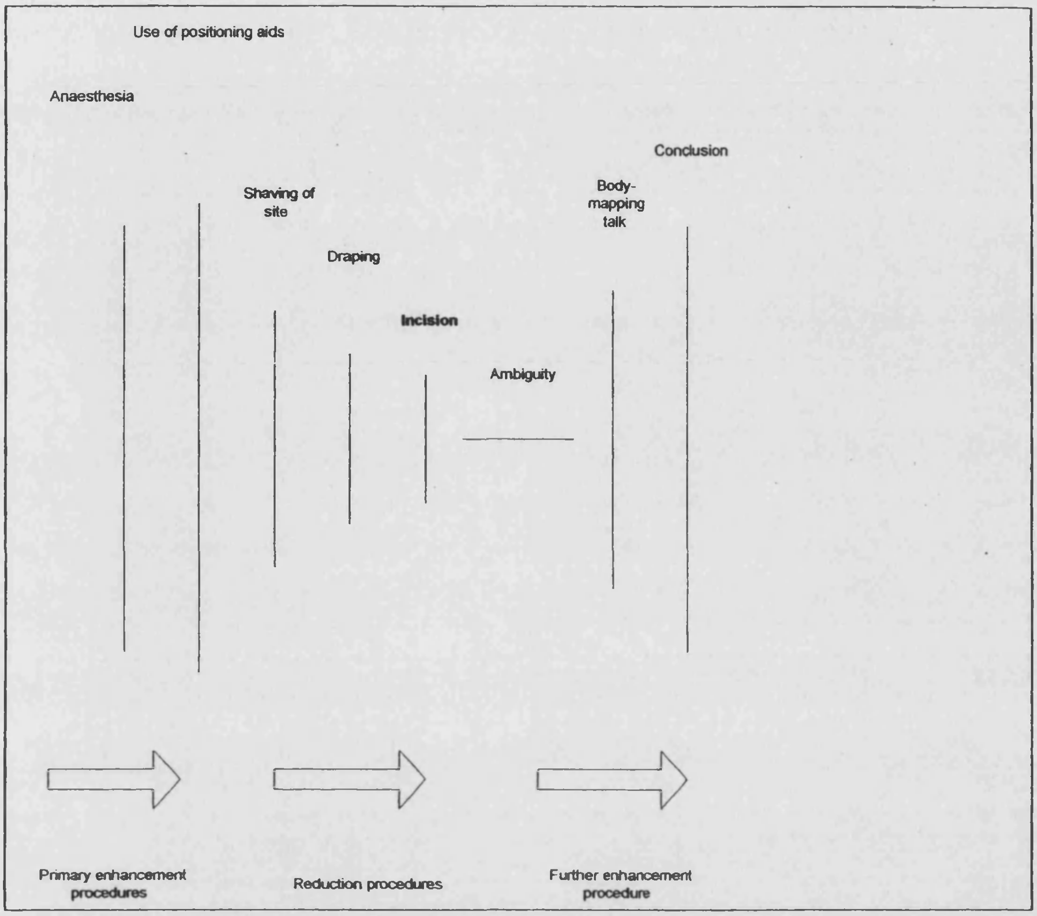


Fig 9: To show the use of primary enhancement and reduction procedures, plus *further enhancement procedures* (in this case, the use of language) in an ambiguous situation (operation 3), by the respondent RH.

This diagram shows how RH's strategy for dealing with an uncertain situation both resembled, and differed from both that of James, and also that shown in the 'idealised model' (Fig 7). The primary enhancement, and especially the reduction procedures, were less stringently applied (as indicated by the shorter length of the relevant lines in comparison with Figs 7 and 8). However, in this complicated situation, RH (like James in the routine one recounted earlier) used a *further enhancement procedure* (although in this case language, rather than a 'visual aid') to assist in dealing with it. Further enhancement procedures are discussed more fully in the next chapter.

The importance of touch-sense in addition to vision is particularly well illustrated in this episode. RH expressed concern on more than one occasion that the animal's reproductive organs did not 'feel right'. Although he had enlarged the incision, it was still not possible for him to actually see the troublesome ovary, due both to the still relatively small size of the incision, and the abnormalities in the shape, size and position of the ovary.

Another interesting point arising from this observation, is the way in which RH temporarily abandoned one aspect of the task that he was having trouble with (the second ovary), and turned instead to another aspect (removing the caudal part of the reproductive system). Once this was successfully accomplished, he then returned to the problematic area, and successfully completed this aspect also. David Klahr (2000) showed similar occurrences in relation to experiments where subjects were asked to solve computer programming problems. When investigating a confusing aspect of an experimental solution, his participants momentarily deferred this investigation, and switched instead to exploring a different aspect. Klahr described this behaviour in terms of what he called the PUSH (put up on stack) heuristic, and proposed that its use allows the generation and activation of novel ideas and solutions in 'experimental' situations. This situation could indeed be thought about as 'experimental' for RH, in that it was not the same as any he had previously encountered, and for a short while at least, he could not predict the outcome with any degree of certainty.

8.8 Summary and conclusions

In this chapter I have discussed some of the ways in which surgical operations are categorised or classified by surgeons. I have devised (and revised) a matrix to enable individual procedures to be categorised in relation to two methods of classification that were suggested by veterinary surgeon respondents. This may be important because ways in which practitioners *themselves* classify or categorise the tasks they carry out, may yield some insight into differences in the ways they think about, and approach them. As we have previously seen however, difficulties occur in instances where categories *(any* categories) are applied too stringently. The respondent BM's classification of surgical cases into emergencies and non-emergencies for example is unhelpful if attempts are made to apply it absolutely, due to different understandings that are possible in relation to the term 'emergency'.

Of course, its application in this manner was never envisaged nor intended by BM. His emergency / non-emergency distinction was a spur-of the-moment one, made in the course of a brief telephone conversation. It was a rule of thumb, an heuristic. Most of the time it works, but there will be some instances where it does not. Such heuristics are used by experts within a form-of-life in precisely this way, as a means by which uncertainty can be quickly be mediated, thereby allowing effective (and immediate) action to be taken.

Heuristics also aid in the communication of knowledge within a form-of-life. RH and JH also contributed their own heuristics, relating to where the incision should be made for a cat spay operation via the flank. They are not absolute rules; they cannot be, since RH and JH each contributed different ones. JH explicitly termed them 'rules of thumb', and stated that others exist. Such rules are only of limited use to novices such as Richard, and even competent performers like James still for much of the time require rules which are much more hard and fast - algorithms - context-free rules which can be successfully applied in *all* situations. In 'normal' situations, where 'the rules' (algorithmic rules) are followed, procedures can thereby be successfully carried out by those with limited experience. Of course, it takes a long time to abide by 'the rules', and one is thrown in situations where aspects of the world (or in this case, aspects of anatomy) fail to do likewise.

What I have done in my attempts to classify surgical operations, is to show what happens when 'the rules' are applied rigidly, in the manner for example of Richard or James at the time of these observations. For example, the matrix could be thought about as an algorithm, or context-free rule that would work in every situation (as in Fig 3 perhaps). Difficulties soon arose however when I attempted to apply it to actual cases, particularly ambiguous ones, such as RH's second operation. In this situation, although the procedure started out as seeming to fit perfectly well into a category, it quite quickly became obvious that it did not. If thought about in this way, the matrix (particularly the first version, shown in Fig 3) is misleading, or a failure in respect of the classification of surgical operations. However, the matrix could equally well be considered heuristically, which is what I have attempted to do in Fig 4. This device is more flexible and inclusive, at least in respect of the meaning of the term 'emergency'.

Like this, it can be thought about as a rule of thumb that will work for most cases (indeed all of those considered here), but not necessarily for all possible cases. As I pointed out earlier, it is perfectly conceivable that there are other operations which would not fit into any of the eight categories of the revised matrix in Fig 4. However, this version allows for more variation, and can still work even for operation 3, allowing as it does that a procedure may change from one type to another during its actual course. If thought about in this way, the matrix provides a useful aid to analysis, allowing progress. Classification is useful, it would appear, if applied flexibly. Perhaps this is expressed badly, since even novices' rigid rules are after all useful *to them.* They are useful only for a short while though. As Dreyfus and Dreyfus (1986) pointed out, they have eventually to be put aside, or perhaps revised in the light of experience (a bit like my matrix) in order to allow progress.

I have described in some detail the preparatory procedures as related to both surgeons and their patients which take place prior to routine veterinary surgery. I have used diagrammatic models alongside my text to show where differences exist between the idealised 'methods' of textbooks, and the actual methods that are used in practice. These differences call into question the received wisdom which states that the sole or main purpose of these procedures is to maintain sterility and prevent the occurrence of post-operative infection. I have identified an alternative role for the procedures, that of *visual aids,* or enhancement and reduction tools for the purpose of mapping the body; locating and differentiating internal organs, and relating the internal anatomy to the external.

In examining three ovario-hysterectomy operations, and taking into account also comments from other practitioners in relation to this procedure (and in relation to other procedures by means of the classification matrices), I have begun to show the ways in which these strategies may be differentially used by surgeons with differing levels of experience. Enhancement and reduction procedures are considered in relation to ways in which actual bodies are made to relate to, or merge with, anatomical representations of them. For the 'expert', this feat has already been largely accomplished; they no longer need to devote much in the way of mental resources to bodymapping, but can concentrate instead more upon what they see as the real problems and hazards of the procedure. This evidence supports the stage models of skill acquisition that were discussed in chapter 2.

One respondent described this 'coming to terms' with anatomy, in respect of a 'mental library' of cases that she had built up over the years. JH's 'mental library' could be thought about quite literally as a pattern matching exercise. Each new case is compared with all of the previous cases that she has encountered, a match is made, and she deals with *this* instance in the same sort of way to a previous, similar instance. This would however take quite a long time; pattern matching makes considerable demands upon working memory (which is one reason why computers tend to be better at it than humans). I have never noticed expert subjects pausing prior to engaging with a task whilst all this processing is going on, and neither is there any evidence of this in the literature. Also, if pattern-matching were sufficient explanation, in cases where no match were found, surely our 'expert' would be unable to proceed? Pattern-matching cannot account for innovation, and accounts only poorly for learning. JH's perception of similarities between this case and another does not depend upon memory alone, but upon experience and the meaning that her experiences hold for her. As Merleau-Ponty (1962 p.2) pointed out, *'To perceive is not to experience... impressions accompanied by memories capable of clinching them; it is to see, standing forth from a cluster of data, an immanent significance without which no appeal to memory is possible. To perceive is not to remember'.*

It is far more likely that JH stores her 'library' of cases as a complex and abstract mental model which can be instantiated in various ways, and immediately as required. Neither does it matter if a particular instance is not *exactly* the same as a previous one; there will be similarities, some *aspects* of it will be the same. The respondent RH was observed to demonstrate the ability to instantiate his mental model of a situation, *and still successfully carry out a task even though it did not equate perfectly with this mental model,* and JH and BM showed indications of such ability also. They can use aspects of their mental model, and *abduce* from these, to a satisfactory solution to the problem or variation encountered. This is not a logical process, so cannot be accounted for by deductive or inductive modes of inference[21]. In the course of this abductive process, it is likely that a respondent's mental model of a particular procedure undergoes some form of modification. On future occasions if similar situations were encountered to that dealt with in operation 3, I would surmise that RH would in time deal with them in his customary manner, apparently without very much thought at all.

Shelley (1996) described instances where, in archaeological research, a leap may be made from apparently insignificant facts which can be observed, to a complex reality which cannot. These facts can be ordered into a sequence, or narrative, as a means of forming a tentative explanation of what is perceived (we have already established that perception should not necessarily be thought about merely in terms of the *visual,* since the full range of sensory modalities may be used). Such a narrative enables a course of action. Narrative is a linguistic form, and it seems only reasonable to assume that it might be accompanied by language *use.* In RH's second operation, he used talk as a bodymapping aid in just such a way, verbally identifying what he observed in relation to the abnormalities in the reproductive system, and possible strategies for dealing with it; he was, in effect, 'telling the story' of this particular operation as it unfolded.

I have categorised this language use as a 'further enhancement procedure', and will discuss this in relation to others used in a similar way, in the next chapter, where I continue with discussions of these and similar matters, but in relation this time to procedures which are in no sense routine. Via observations of orthopaedic operations, I will show further instances of bodymapping by surgeons, both the operating surgeons themselves, and by others who are 'merely' observing.

NOTES

1 I met Dr Jones as a fellow presenter at a conference at the University of East Anglia, entitled 'Animals, Vets and Vermin in Medical History' (28-29 April 2000).

2 Eg, *Animal Hospital* and *Vets in Practice* shown on BBC TV.

3 Eg, *Casualty* and *Holby City* shown on BBC TV.

4 'Textbook' method as demonstrated in GDBA (1996) training video

5 The term 'cranial' is an aid in anatomical direction-finding; it means 'towards the animal's head.' See Fig 1.1.

6 RH spoke of how a colleague had laughed at him for taking as long as 10 minutes to do a cat spay. This recalls references to the 'masculine society of surgeons' described by Cassell (1987 p. 231).

7 When an animal is placed in 'dorsal recumbency' it is positioned on its back with its chest and abdomen facing uppermost.

8 'Cranially' means 'towards the animal's head'. See Fig 1-1.

9 'Caudally' means 'towards the animal's tail'. See Fig 1-1.

10 An example that I have used in conference presentations is to be found in Boyd (1991, p.218). Unfortunately it has not been possible to obtain permission to reproduce this here.

11 *Hands On Virtual Reality Simulation* presented by Dr Nick Taffinder at the Imperial College of Science, Technology and medicine as part of the British Association Festival of Science (9 September 2000).

12 'Brachycephalic' is a term used in animal anatomy to describe the skull shape

of short-nosed dog breeds.

13 In animals with pigmented skin, it is harder to locate the subcutaneous blood vessels via which anaesthetic agents and other drugs are injected.

14 Another example of an heuristic or rule of thumb. This information would be of little value to those who were not familiar with the appearance and consistency of different types of body fat.

15 See Appendix 1 for the format used to record uses of off-task and on-task talk.

16 German shepherd dog; a popular breed also know as Alsation.

17 Of anaesthetic.

18 Of anaesthetic.

19 To indicate the insertion of an endotracheal tube.

20 Hirschauer (1991). See note 21, p.316. Kirk R.M. (1978) *Chirurgische Techniken.* Stuttgart and New York: Thieme.

21 The model of abduction to which I refer (which was developed by Gooding, eg 1996) shows how inductive and deductive processes fit into a larger abductive 'cycle.' Induction and deduction are logical processes (see chapter 4). Abduction can account for those aspects or parts of activities which do not fit this model. Thanks to Professor Gooding for pointing this out.

CHAPTER 9: PUTTING THINGS (BACK) TOGETHER: EXAMPLES FROM ORTHOPAEDIC SURGERY

'Many but not all vets would prefer to refer this sort of op to a specialist, but some prefer to do it themselves, or the owners want them to for reasons of cost and so on. There are so many ways of doing it, I guess because there isn't a definite way that will work in every situation. Sometimes it just doesn't work. Its a procedure that is fraught with complications. But if someone is doing several a day or a week, they're bound to have more idea than someone else who maybe does one every couple of months or so'.
JH.

Orthopaedics, in veterinary science as in medicine, is that branch of surgery which is concerned with the diagnosis and treatment of injuries, deformities and diseases of the bones, joints, ligaments and muscles, and the nerve supply to them. In the above exerpt, JH was discussing 'cruciate operations'- surgery carried out to repair the stifle (knee) joint after disruption of the cruciate ligaments[1] by trauma. As her comments suggest, orthopaedic operations (and the ways in which vets think about them) are very different from spays in a number of important respects, quite apart from the obvious one of their concern with different body-parts. Firstly, orthopaedic procedures are generally neither routine, nor elective. All of the operations described here for instance, were carried out in attempts to repair serious injuries sustained as a result of accidents.

Secondly, and linked to this, these operations are acknowledged to be 'harder'[2] than many of the other types of surgery carried out in veterinary practice. Such 'second-order' knowledge (Pinch, Collins and Carbone 1996; 1997) about surgical operations directly influences whether or not an individual surgeon will attempt them. As JH's comments indicate, many will not, preferring to refer such cases to a specialist. However, as the example of operation 5 (correction of a disunited hard palate in the cat) shows, even relatively inexperienced surgeons may attempt 'difficult' procedures in situations where there are more experienced colleagues on hand to offer advice and assistance.

That they are 'harder' to accomplish successfully does not imply that the equipment used to carry out these procedures is necessarily more sophisticated than that used for the routine operations encountered previously. Although greater *numbers* of instruments tend to be used, orthopaedics employs carpenters' tools; drills, screws, and implements that look very much like hammers and chisels (and are used in very much the same sort of way), alongside the usual scalpels, clamps, scissors and sutures. Although these operations undoubtedly require considerable manual dexterity and frequently also some degree of physical strength, it is likely that the main reason why they are considered so difficult is because they are relatively infrequently carried out, and as a result most surgeons get little opportunity to attain any level of proficiency or expertise in their accomplishment. Also, as JH pointed out, there is seldom one, definitive method of carrying out these procedures, but a number of possible alternatives. It is often therefore a matter of some dispute as to which of these is the 'best'. From observations of these operations, and from verbal evidence provided by the 'expert' referral surgeon, it can be surmised that skilled judgement is required to ascertain which particular method is most appropriate for any one individual operation.

Thirdly, the orthopaedic operations discussed here are considered to be 'less tactile' than soft-tissue procedures such as spays. They can therefore be situated in Box 7 in the bottom row of our revised matrix (see Fig 10 below). The 'less tactile' nature of orthopaedic operations indicates that they may be at the same time perhaps 'more visual'. Certainly, bones are easier to differentiate visually than abdominal organs, (or at least they are from the point of view of an observing bystander), and surgeons themselves attach great importance to the use of visual images such as radiographs and anatomical pictures in orthopaedic surgery.

	Type A 'Non-emergency procedure'	Type B1 'emergency'	Type B2 'emergency'	Type B3 'emergency'
More tactile	1	2	3	4
Less tactile	5	6	7 xxxxx	8

Fig 10: Diagram to show the position within the revised classification matrix of operations 4,5,6,7 and 8

Despite these important differences there are similarities too, that exist between these operations and the others discussed previously. The pre-operative preparatory procedures for example are identical, (or at least their textbook descriptions are), and orthopaedic operations follow the same general pattern as spay operations, progressing through the same stages from induction of anaesthesia to closure, although some of these stages tend to last rather longer. It is worth remembering though, that the length of time taken to perform an operation depends not only upon the nature of the operation itself (eg, how ‘hard’ it is), but also upon the amount of experience that the operating surgeon has in carrying out the procedure in question. For example in terms of actual duration, IM (orthopaedic specialist respondent) took hardly any longer to carry out a cruciate repair than did recently-qualified James (encountered in operation 1), to carry out a routine spay operation.

In operations 1 and 2 in the previous chapter, I showed how (ostensibly standardised) pre-operative preparations were differentially applied in the case of routine operations. I proposed that these procedures might therefore have another purpose quite apart from their stated one of infection prevention, that of *enhancement and reduction tools* to assist with the bodymapping process. It was argued that their differential application may be linked to differences in the amount of experience that surgeons had accrued in relation to this operation, and consequent variation in the necessity for visual aids to bodymapping. As we will see however, for all of the procedures discussed in this chapter except for operation 5, considerable care was taken by *all* surgeons (including the 'expert' referral surgeon) over this initial preparation of the patient-body.

The use of language for bodymapping purposes (in respect of surgeons actually *talking* their way through the identification of the various organs and tissues they encountered), was discussed in relation to operation 3. It was proposed that this use of language provided a **further enhancement procedure** in uncertain situations. The newly qualified surgeon James whom we met in operation 1, used instead of language, what he termed a 'visual aid' (his explanation for his use of swabs to cover 'unwanted' organs, and so presumably enable him to concentrate his attention more keenly upon relevant ones) for further enhancement purposes. Lynch and Woolgar (1990 p.vii) argued that scientists construct and use representations, or 'inscriptions' in '*contextually organised and contextually sensitive ways*'. They included *'verbal accounts*' (ibid p.4) along with objects such as *'core extracts, tissue cultures and residues impressed within graphic matrices, ordered, shaped and filtered samples, carefully aligned photographic traces and chart recordings*, as well as *'pictures of natural objects'* in their generic term 'inscriptions'. It is contended here that surgeons' enhancement and reduction procedures, in all of their guises, are used after the manner of inscriptions, as scientists use the above, and other, similar representations; to 'simplify' objects in the real world, thus allowing them to be known, and manipulated.

In this chapter, the notion of further enhancement procedures (both 'visual' and 'verbal') will be explored in the context of non-routine operations. The use of these procedures by both experienced and less experienced surgeons will be discussed, and linked to this, the differences that exist between textbook accounts and actual practice. A further point of interest is the role played by other surgeons present (ie, apart from the operating surgeon(s) in relation to the operation presently being performed, and visual and verbal representations of it.

This chapter is divided into three sections, each relating to a *different* procedure. The first section (operation 4) concerns the repair of a compound fracture of the forelimb. The second (operation 5) relates to the repair of a cat's hard palate[3] which had been damaged as a result of a road traffic accident. In both of these sections, only one instance of the procedure in question is discussed. In the third section, I compare three separate instances of the repair of the cruciate ligaments which stabilise the knee joint (operations 6, 7 and 8). Operations 6 and 7 were carried out by an orthopaedic specialist, and operation 8 by an experienced general surgeon.

9.1: The compound fracture - operation 4

'Compound fractures are those in which the skin is injured, so that a direct or indirect communication between the fracture and the outside air exists. The broken end of the bone very often penetrates through the skin and is found exposed. Bleeding is apt to be severe; infection of the ends of the bones with pathogenic organisms may occur'.
(Black's Veterinary Dictionary).

This example is interesting in that it shows how an experienced general surgeon (as opposed for instance, to the relatively inexperienced Alison, or the orthopaedic specialist IM whom we meet further on), and also his colleagues, made use of a range of 'visual aids' during the course of a difficult and lengthy operation. The surgery was carried out upon a dog which had been injured as a result of a road traffic accident. The x-rays clearly showed that both the radius and the ulna (the long bones of the lower forelimb) had been broken and were totally disunited. Jagged ends of bone were visibly protruding from an open wound in the lower part of the limb. This type of injury is known as a compound fracture. The following is lifted almost in its entirety from my field notes. Audio-taping had unfortunately not been possible in this instance. Therefore, I show verbatim quotes in inverted commas. Other verbalisations are approximations which were constructed as accurately as possible soon afterwards, from written notes and from memory. WW is the operating surgeon, and VN the assisting nurse. Other participants are introduced in the fieldnotes.

X-rays were up on the viewer (2 views again), and the break was clearly visible. There was also a textbook open on the operating table, showing text and line diagrams. WW positioned the dog in lateral recumbency,[4] *with the unaffected forelimb tied to the table, across its face, enabling access to the medial (inside) aspect of the other forelimb. The limb had already been shaved, but WW carefully draped the patient himself using rectangular cloths and towel clips. There was also a little drawstring bag thing over the foot. The VN assisting turned the book so that WW could see it from where he was standing / sitting. It was a particularly tricky procedure 'because of a big vessel' (cephalic vein) crossing the radius just about where the break was, and the necessity therefore to place the plate and screws in position under this vessel without damaging it. The paths of the blood vessels were visible under the shaved skin.*

WW started off (sitting) to make the incision, but then stood 'to see better', incising carefully and slowly. He started with the scalpel, but then used forceps and pointed scissors. The radio was playing quietly in the background. WW continued, sometimes using the point of the scissors like a scalpel. A second vet arrived, glanced at what his colleague was doing, made some remark (which I did not catch), and started to consult the textbook on the operating table on another matter. WW clamped leaking blood vessels, again 'in order to see better', and was continually swabbing away blood from the wound. Gradually he became able to realign the two ends of the radius bone. This was quite hard physical work, from the effort that WW seemed to be expending. He clamped another vessel, there was still a lot of blood, and he kept mopping at the wound whilst waiting for the nurse to bring from somewhere else a plate of the right size to stabilize the bone. He sent the VN for a larger plate again, after trying the initial one she brought against the bone for size. It took a long time to place the plate. It was necessary to make the incision bigger, which involved more mopping of blood and clamping of vessels. There was a pool of blood and a number of *used swabs and towels on the floor by this point. Difficult because of position of the cephalic vein, the plate needed to be placed beneath it, and the bone needed to be drilled so that screws could be inserted to hold it in place. Caught a glimpse of the title page of the textbook: A Guide to Canine and Feline Orthopaedic Surgery.*

Someone entered the room to enquire about a bill. WW replied briefly and tersely, fumbling for the required tools. WW was (uncharacteristically, as I had found out by now) quiet for most of the time. Tried to drill bone. Inserted screw, but hole not big enough, needed a bigger drill bit. Measured drill against screw again, very carefully this time. Drilled again, mopped up more blood. Screw started to go in this time, finished off with a second screw driver. 'The aim is, a nice straight leg' not sure whether WW meant this remark for me, for himself for the nurse? More mopping. Second vet came back in (BMc). WW asked him to scrub up, then changed his mind. 'Oh don 't worry, I've done it now'. BMc did so anyway. Others came in to see what is going on, to consult the textbook, the xrays on viewer, talk about what they saw in the pictures, on the plates and on the table. Someone remarked 'At least its well clear of the joint' Someone else agreed 'Good place to break it, plenty of room to get a plate in' WW obviously finding it more difficult than their remarks would indicate.

BMc started to drill whilst WW held the limb and watched closely, giving instructions. Seemed to be easier and quicker with another pair of hands and eyes. Drill bent. WW straightened it with forceps, tried again. More problems, lots of blood. Someone said 'there's the cephalic vein.' I don't think they breached it though, not enough blood for that. More drilling, mopping, screwing, still having trouble with the cephalic vein. Short, terse comments only passed between the colleagues. Plate now screwed in place, limb indeed looked much straighter. BMc now holding artery forceps, tied off vessel causing the trouble. Vets glanced at the xrays now and again. Book largely ignored (but WW had looked at it prior to starting the procedure). WW still giving instructions to BMc.

Now suturing, vets started to talk about unrelated matters. Then BMc left. Not needed anymore. Suturing all the layers took a long time. I asked about the break in the ulna (only the radius has been repaired). WW replied that there is need *only to repair the radius, and the ulna is thereby pulled back into the correct position and would knit together on its own. Still suturing layers*

Administrator returned, 'Can I speak to you now'? WW assented. Talk about VAT, new car for practice, etc. Suturing top layer now. I asked if WW would need to re-xray the leg now the plate was in place. WW replied not; he is quite happy with it now.

This account is noteworthy in three respects. Firstly, in relation to the meticulous attention paid by experienced surgeon WW to the primary enhancement and reduction procedures of positioning and draping the patient. Secondly, the social interactions that were going on throughout. Thirdly, and linked to this, in respect of the uses made (by all of the surgeons present), of the radiographs and the surgical text.

9.1.1: Positioning and draping: creating a window into a world...

Although WW's preparation of his own 'surgeon's body' (Hirschauer 1991) was fairly perfunctory in that it was limited to washing his hands and putting on a gown and a plastic apron over his everyday clothing, (he wore no head covering, mask or gloves), his preparation of the *patient's* body was very thorough. He carefully positioned and draped the anaesthetised patient himself, rather than (as often happens) instructing a nurse to do so.

WW first of all 'tried out' a number of different positions on the inert body of the animal before fixing upon the one he eventually used, which he felt allowed the best view of, and access to the site of the fracture. Using rectangular drapes and towel clips, he then visually 'cut off' the injured leg (which had already been shaved and swabbed with antiseptic solution by the nurse) from the rest of the animal's body. Even the foot of the injured leg was covered, with something resembling a small drawstring bag. This effectively created a 'window' through which he would work, and all that was visible through this window was the injured portion of the leg.

WW was silent during these preparations, intent upon what he was doing. It can be surmised that draping the animal himself, rather than having the nurse do so, may have allowed him to focus mentally (as well as *physically* via the drapes themselves) upon the injured area, effectively *reducing* the animal's body to a single, shaved forelimb from shoulder joint to carpus.[5] This observation of a rather 'specialised' method of looking at something (ie, 'looking at it' for a very specific purpose) accords with Merleau-Ponty's (1962) argument that we focus our attention in normal, everyday vision upon a particular object by *reducing* our attention to those surrounding it. This supports the view discussed in the previous chapter, that a primary purpose of draping is as a 'visual aid' to bodymapping in surgery; an important 'reduction procedure' which reduces the animal's gross anatomy to the particular area of immediate concern.

9.1.2 Language and social interaction

I had initially assumed that surgeons' bodymapping strategies would be largely visual in nature, but the data points also to the importance of language and social interaction for this purpose (allowing that the term 'language' encompasses both speech and text, and that 'social interaction' is something more than 'talking' alone). Perhaps the apparent importance of pictures *and* language together as bodymapping aids is not unduly surprising if we consider first of all the historical development of anatomical texts which was touched upon in chapter 3. These texts throughout their history have consisted of both pictures and language; anatomical illustrations and written text *which are intended for use together.* This format moreover is not limited to anatomical or surgical texts. On the contrary, it is general to works of this kind, which are intended to provide demonstration or instruction in relation to the performance of skilled practical activities. Numerous other examples, both historical and present-day can be drawn upon, from Hooke's *Micrographia* through to modern engineering manuals.

Secondly, the importance of social interaction in constructing *scientific* knowledge was discussed in chapter 2, and it is hardly surprising in the light of this that it seems to play an important part in the construction of the *applied scientific* knowledge of surgery also. I refer here to both the 'body of surgical knowledge' in general, and to the specific body of 'personal' knowledge that is accrued by individual surgeons. I therefore consider the use of language *alongside visual images* as it relates to bodymapping, and social interaction as a strategy whereby complex activities such as mapping the body become possible.

The operations discussed in the previous chapter were all carried out by a single surgeon, assisted by a nurse. This allowed only very limited opportunities for social interaction, which were not on the whole particularly interesting from the point of view of this topic. In this instance however, not only were there two surgeons directly involved in carrying out the procedure, but several others were also present on the periphery of what was going on, for varying lengths of time. Language use was therefore both more varied and more complex than that encountered previously, and also of considerable interest in relation to bodymapping. It is to be noted for example that there were two 'sets' of social interactions going on during this episode; those in which operating surgeon WW was involved, and those that were going on peripherally, in which, although he was present throughout, and the topic was the surgery that he was performing, he took no part.

For WW, this was both a difficult and a physically exhausting operation. For most of the time, he remained silent, uttering only occasional terse comments and instructions to the nurse, and later to the surgeon BMc who assisted him. This was no time for off-task talk. He spoke very shortly to the administrator who came in to ask his advice about an unrelated matter, making it quite plain that he was not to be interrupted. However, once the procedure was almost completed and he had reached the suturing stage, he visibly relaxed. At this point, he and BMc started to talk about unrelated matters, and he consented to deal with the administrator's query. He also indicated to me his willingness to answer any questions.

WW's sparse and somewhat abrupt interactions with his colleague BMc during these difficult manipulations were significant in that he appeared merely to use this other experienced surgeon as an 'extra pair of hands'. There was no discussion between the two surgeons about the fracture, or appropriate strategies for repairing it. Rather than it being a fully collaborative effort, by which I mean the exchange of discussion and suggestions between the surgeons, as well as assistance provided with physical manipulations, (which I had expected, and which as we will see, did actually happen in operation 5), WW simply issued instructions, and BMc simply followed them. However, perhaps this was all that was required. These two men had been working together for some years, and it could be that all that needed to be said between them on this subject had long since passed, a result of their familiarity with their craft, with each other, and with their respective ways of working.

Despite its difficult nature, at no stage during this procedure did WW engage in bodymapping talk as RH had done in operation 3. This could be because the difficulties involved were not related to the location or differentiation of organs, abnormal or otherwise. In this instance (at least for WW), the necessary bodymapping had already been done. This seems in any case to be visually less complex than for abdominal surgery (despite the fact that the operation itself is considered 'harder'). There is after all very little that is immediately visible within a forelimb other than bone, muscle and major blood vessels. After his careful initial preparations, WW had made the incision in such a way that the bones and other tissues involved could clearly be seen and identified (although they periodically became obscured by large quantities of blood that had to be mopped away). The difficulties seemed instead to lie in the actual manipulation of the bones and instruments, and the position of the large blood vessel clearly visible directly across the point at which the plate had to be secured to fix the broken bone in place.

Although WW spoke little during this procedure, the same cannot be said for the other practice vets. Whilst WW was operating (both before and after BMc arrived on the scene to assist), other colleagues gathered round, passing evaluative comments upon the injury, the operation, and especially the *images,* both the radiographs and the textbook illustrations. It appeared in fact that they paid considerably more attention to the pictures than to what was taking place on the operating table. Here was plenty of bodymapping talk, though it appeared to be related more to the 'anatomical body' of the pictures than to the actual body of the patient. Some of the comments that were made seemed to be connected only tenuously with the operation that was actually taking place (although they undoubtedly related to *some* incidence of compound fracture repair, perhaps to the 'idealised operation' shown in the neat line diagrams of the textbook). The comment made by one observer in relation to the injury that it was a *'Good place to break it, plenty of room to get a plate in'* for instance, seemed to be made entirely in respect of these visual images, since it totally belied the problems that WW was having, (even with the added use of BMc's obedient hands) in manipulating the bones, the instruments and in trying to navigate carefully around the troublesome blood vessel, all of which were obscured by the presence of considerable quantities of blood. WW completely ignored this peripheral discussion, as did BMc during the time he was assisting, to such a point in fact, that they seemed to be quite unaware of it.

9.1.3: Uses of visual images

In a similar manner to the different ways in which *talk* was used by the operating surgeons, and by those on the periphery, there were different uses also made of the available visual images. Both groups used them for bodymapping purposes, although it would appear that they may have been engaged in mapping different 'bodies'. WW's concern was the body of the patient on the operating table in front of him, or at least that area of it between the shoulder and the wrist of one forelimb. The other surgeons however appeared to be more concerned with mapping the 'anatomical body' as it appeared in the radiographs and textbook illustrations.

Ethnographic studies of laboratories (Latour and Woolgar 1979; Latour 1990) have noted scientists' tendency to '*drift from watching confusing 3D objects to inspecting 2D images that have been made less confusing*' (Latour 1990 p.39). WW's colleagues too, appeared to be interacting here, neither with him nor with the difficult procedure that he was engaged in, but with simplified, idealised representations of it. Neither were they concentrating on one particular representation, *but upon the full range available,* the radiographs, (as usual, taken from two different views), together with the pictures in the surgical manual. Like Latour' s scientists, they too, manipulated, superimposed and combined these 'inscriptions' (Latour and Woolgar 1979). The images, and the surgeons' use of them provide examples of the 'visual language' (Rudwick 1976) of surgery. The only persons present who were not involved in these peripheral interactions (apart from the assisting nurse and myself) were WW *himself* (who seemed to ignore them), and BMc once he had started to assist, that is, once he had become involved in the performance of the 'actual' operation.

In contrast, WW's own use of these images (modelled in Fig 11 below) was very different. That he did in fact use them along the lines of 'further enhancement procedures' at the commencement of the operation can be in little doubt. The radiographs were displayed on the viewer next to him, and he had taken the trouble to look for the surgical text amongst the collection of books owned by the practice, and had taken it with him to the operating table. However, having initially consulted the textbook, he then largely ignored it once the operation was under way. The x-ray images too, were examined carefully at the outset, but only glanced at casually every now and again after this. This could be because, since the operative site was frequently obscured by blood, the pictures were only of limited use for purposes of visual comparison. As a consequence, experienced surgeon WW would have had to rely largely upon another resource; the internalised 'anatomical body' that he had developed through his training and experience. Perhaps he was engaged in making mental comparisons of this with the actual injury, and making adjustments (both mental and actual) to bring the damaged reality in line with his *mental* model of the intact forelimb.

This collection of images was therefore used in different ways by two groups of surgeons. WW (and later BMc) used them as 'visual aids' (or further enhancement tools) for operating, the textbook initially (chiefly in respect, I would surmise, of the path of the obstructing cephalic vein), and the x-rays for reference intermittently. The other surgeons used them as a focus for discussion and also perhaps for reflection and comparison in relation to quite another 'operation'. Such an 'imagined' procedure has obvious links with *actual* procedures; the one going on at the time, obviously, but perhaps also ones in which the surgeons had participated previously, or that they had observed, heard or read about, or possibly ones that they would perform themselves in the future.

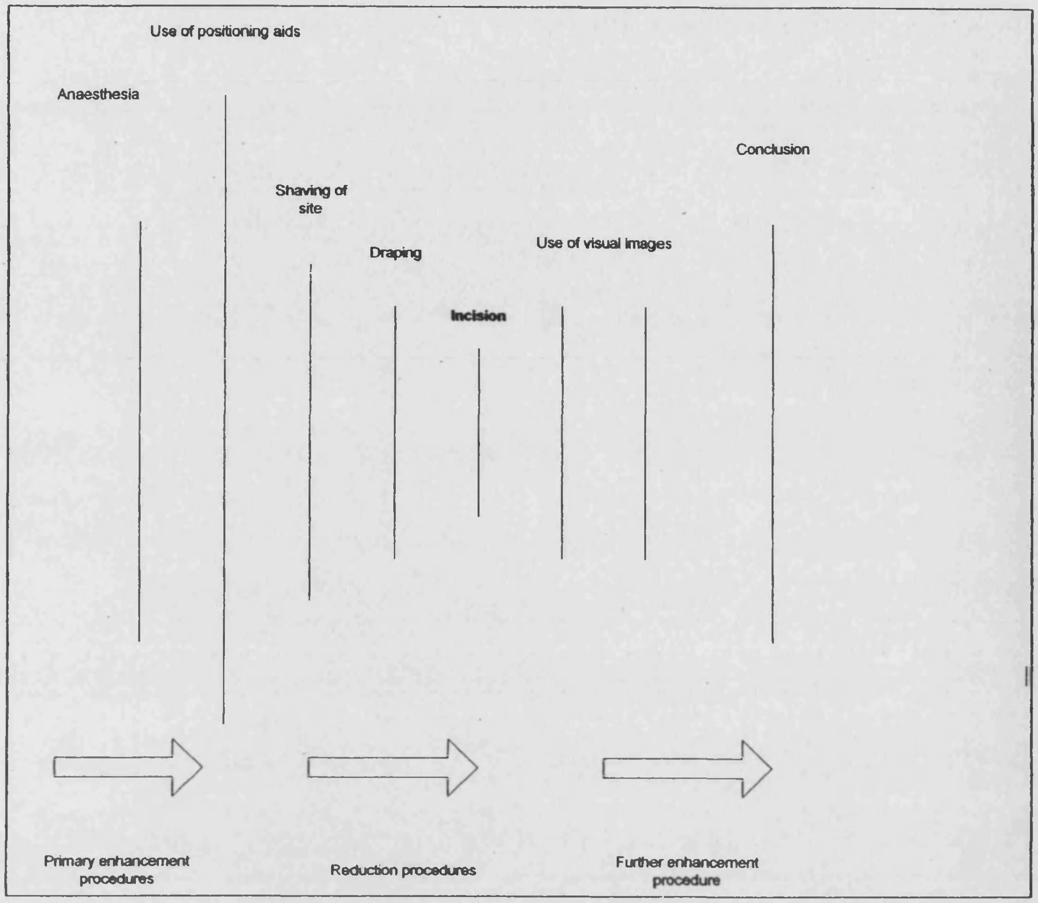


Fig. 11: Diagram to show WW's use of visual images as 'further enhancement procedures' when carrying out a compound fracture repair

This 'virtual' operation that was taking place alongside the observed 'actual' one calls to mind the links which exist between actual acts and situations, and mental simulations of them. Alongside the *biological* advantages of mental simulations, which avoid the costly necessity of having to try things out for real each time, there exist others. Gooding (1990) drew links between the roles of thought experimentation and real experiments in science. According to his analysis, thought experiments are 'distillations' of actual practice in the real world, which 'idealize' the key components of real experiments, including the skills necessary to carry them out. What WW's colleagues appeared to be participating in, was the 'idealized' repair of a compound fracture, like that inscribed in the surgical text, yet with links also to the shattered and bleeding reality on the operating table with which WW wrestled and against which he made approximate and imperfect measurements. I would therefore argue that such 'virtual' operations, like 'actual' ones, provide a context within which surgeons learn to become skilled 'operators'.

In the next excerpt, another example of surgery involving two groups of surgeons is shown. The operating surgeon on this occasion was Alison, a young vet who had not carried out this particular procedure before. Alison was assisted by Ben, a more experienced colleague. This operation was 'properly' collaborative in that the assistance rendered this time took the form of overt verbal discussion, instruction and encouragement as well as practical assistance.

9.2 The case of the separated hard palate -operation 5

'Severe injury to the hard palate is not uncommonly seen in cats that have fallen from a height, and suturing may be required'
(Black's Veterinary Dictionary).

Self: *Can I ask if you use pictures, for example, at one of the C.... practices, I saw complex orthopaedic procedures being carried out, and there were books open on the table, and radiographs on the viewer, and people seemed to be using all of them together?*
JH: *Yes, I use anatomy books, especially if the procedure is an unfamiliar one. There are surgical texts too, showing the operation at various stages. If it were a complicated orthopaedic thing I would use a radiological text too, these are books showing radiographs of normal anatomy, and indicating how disease processes can cause what you see to deviate from that. Its difficult though, there is such a broad range of 'normal 'forms, its difficult sometimes to distinguish between a normal variant and a pathological condition. I might also ask colleagues, especially more experienced ones, or even send it away to someone for a second opinion if I was really unsure.*

JH's remarks above were particularly interesting in two respects. Firstly, in relation to the notion of 'normal' and 'pathological' anatomy, and the difficulties that can arise in distinguishing between the two. What is and is not 'normal' in relation to bodies is not the simple matter that it would at first appear to be, but rather subject to a good deal of uncertainty and contention. For virtually all bodily parameters, there exists not one single 'normal' model, but a 'normal range' within which some degree of variation occurs. The extent of this 'normal range' is in many instances a source of difficulty and debate among veterinary surgeons, as indeed it is among medics. I discuss this more fully below.

9.2.1 The 'normal' and the 'pathological'

Respondent JH referred to this tension in respect of orthopaedic structures. There is generally speaking no one single 'normal' model, but a number of 'normal variants' that exist. Some of these variants are very similar to so-called pathologies, which are by definition 'abnormal'. Moreover, these categories are not static, but change as scientific research into animal disease throws up more knowledge, or alternative explanations for phenomena. Thus the boundaries between the 'normal' and the 'pathological' are 'dynamic' ones (Rayner 1997), and as such a potential minefield for the inexperienced.

As well as anatomy (which term relates to the *structures* of the body), physiology (the *functions* of the body) is similarly subject to variation. Instead of relying upon physical appearance, many physiological characteristics can be measured in a seemingly more 'objective' way. Again however, these measurements are not absolute, but are considered in relation to a 'reference range' or 'normal range of values' for a species, which is often quite wide. Measurements that fall outside of this range are thus deemed to indicate some or other 'pathology'. This incidentally counts for our own species also! Problems arise in relation to this in a number of respects.

Firstly, different versions exist of what any given 'normal range' comprises. For example, from my own experience of veterinary laboratory work, different sources give slight differences in what counts as the normal range. By way of illustration, the reference range for blood albumin (a protein contained in the blood plasma whose level may be raised as a result of certain liver or kidney conditions) in the dog, is given in one of the texts that I have on hand, as 2.5 - 4.2 g /dl. (Sirois 1995). In another text, (Bloxham 1994), it is quoted as 25-37 g / l. Not only is the range itself slightly different, but the information is encoded in different units, which is also a frequent cause of initial confusion to students. In yet another text (Pratt 1992), my own 'lab handbook' of choice, as opposed to the teaching texts cited previously, the author omits to give a range at all, due to geographical variations that exist in physiological parameters, and also variations in the procedures and instrumentation used in different laboratories!

This brings us to consideration of actual procedures and instrumentation. Differences in the types of instruments used, or in their calibration, will yield different results. More problematic still, blood is an inherently unstable substance. The way a sample is taken, and its treatment afterwards, for example the length of time between sampling and testing, or the temperature at which a sample is stored prior to testing, can and does affect the results quite dramatically. This too is a cause of great concern and uncertainty to novices, who need to be able to 'believe' in their results. Tests are often repeated in order to lessen this uncertainty. Still further uncertainty however originates from what Collins (1986 p.2) called 'experimenter's regress'. Collins defined this as '*a paradox which arises for those who want to use replication as a test of the truth of scientific knowledge claims*'. Since scientific experimentation (like measuring blood parameters) involves skill, it is never certain whether a second experiment (or test) has been done skilfully enough to count as a check on the first one, and so on.

This I feel is linked to uncertainties about measurement more generally. In quite another context, my observations of sculptors in chapter 7 showed how, on occasions where any precise degree of measurement was required, their performance appeared less skilled, and more hesitant and prone to mistakes. The performance of these quite experienced practitioners appeared in fact to revert to that of novices in these instances. What is more, they knew this, seeming to dislike situations where such precise measurement is called for, such as copying (or attempting to copy; as we have seen, such activities were by no means always successful) a three-dimensional object to scale.

The problem that there respondents were experiencing I feel, is related to the use of measurements as algorithms. Copying others' work entails *precise* measurement, as opposed to the much more fluid approach to measurement taken as they went about their 'ordinary', original work. Like experienced vets and veterinary technicians, experienced sculptors tend not to take measurements algorithmically, but rather more in the sense of heuristics, that is, if relevant measurements fit in with other information that is available, they are usually accepted. If not, they may be rejected, or repeated. When however these practitioners are forced to do so for some reason, whether this reason is a client's request for a copy of something, or being confronted with an ambiguous and unfamiliar bodily parameter, their behaviour reverts to something more approaching that of a novice practitioner.

The second issue arising from JH's remarks was related to those occasions where she found it necessary (or beneficial) to use *numbers* of representations as visual aids (or further enhancement procedures) for surgery. In the example below, the respondent Alison is seen doing this, for a difficult and unfamiliar operation. She also 'used' the experience of a colleague (as opposed to merely using his hands as WW had used those of BMc in the first sequence). On this occasion at least, this experience proved to be of greater value than the images to the successful accomplishment of this procedure whose purpose was to re-align and secure in place the two parts of the hard palate of a cat which had suffered facial injuries when it had been struck by a car. In this case the injury requiring orthopaedic surgery was only one of several sustained, and the condition of the animal upon initial presentation had been extremely poor. Orthopaedic repairs are rarely attempted until the patient's condition is stabilised and they are physically able to withstand what may be a long and arduous operation. For this reason, this operation had been delayed for several days after the patient's admission.

Again, there were two groups of surgeons at work here, and effectively two operations taking place; Alison and Ben performed the *actual* surgery, but others were involved in performing its *virtual* counterpart. As before, actual verbalisations are recorded in inverted commas in this sequence. Others are approximated, from field notes and from memory.

Alison now looking at another book, and discussing it (and the 'case' out on the table) with the VN assisting her. Cat with a separated hard palate, rta[6]*, brought in on Sunday, but kept on a drip till today due to poor condition. Book title* <u>*The Skull and Spine*</u>*, pictures and text showing a method of repairing such an injury; 'going to try to wire it back together'. Need to drill either between or through roots of carnassial teeth on both sides, cross over wires and tighten so that the* *hard palate is pulled back together. First problem; drill bits available too big. To me; 'we're going to do this...' Discusses different methods, (from different books) with BMc, who advises her 'If you follow this back further.. ' (with regard to finding the right place to drill), jabbing at the book with a forefinger. Alison tries to use a needle in place of a drill bit, in the brace. The wire needs to go behind the carnassials. Uncertain. Ben (other vet) comes in. She checks with him the site where the wire should go between the roots of the teeth. He looks at the book, and recalls his own previous experiences (has done op before in his native Australia). Admin lady comes in, starts to ask Alison about an insurance form, not a good time, but Alice much less assertive than WW! Perhaps once the site of the 'hole 'for the wire is found it is less fraught?*

Then a receptionist, with another query. Then someone else. Alison says to nurse assisting her: 'Can we go somewhere quiet' Then to receptionist 'No! Go away!' (laughter). The wire is too thick, and pulls out. Now quiet, trying to concentrate. Then Ben comes back 'Ben, this just pulls straight through...'

Ben intervenes to help. 'It might be better if it was on its back' Turns cat from lateral to dorsal recumbency. Alison: 'but now it'll be the wrong way up... it actually is a bit better...' Ben uses a syringe barrel to hold the mouth agape. He holds the mouth of the cat in position, advising Alison, telling her how to position the wire. 'Simple principle, but practically speaking its a different kettle of fish' (of wiring cats 'jaws).

The two vets continue to discuss the cat, standing close together, Ben holding the animal in position, and instructing, the younger vet following his advice whilst actually doing the procedure. BMc comes back in. Alison says to him 'Ben's doing very well, telling me what to do' Ben continues to tell her how the wire should be tightened, describing how it will feel when it is sufficiently tightened but before it reaches breaking point. Ben talking all the time, about the position of the wire, the position of the bones, what problems might arise in the next six weeks while the injury heals, the feel of the wire again. The book is still open, but nobody is looking at it except for another young vet who has come in to watch. Ben still instructing, wire has to cross over to hold the two sides of the hard palate together, going through the gums and between the roots of the teeth. Discussion now of break in lower jaw. Ben and other young vet go to find the *xrays, Alison left to continue. The two men find the xrays, and discussion ensues. Lisa, older female vet comes in. Alison shows her what she and Ben have done, discusses difficulty of drilling through the roots of the teeth. 'Why didn't you use such and such...' Discussion continues.*

The two male vets think that the cat has also broken its lower jaw near the hinge joint. Lisa joins in the discussion. 'The muscles there will act as a natural splint, can't really plate it there'. They go back to the book at this point, Lisa uses the book to support her point of view. Alison is trying to put an NG tube down the cat, but is having trouble, because of swelling to the throat caused by the injury. 'I can 't quite see....' Gets a small torch, peers down the cat's throat. Then measures the tube against the outside of the cat, to gauge where the entrance to the stomach will be. Places the tube, but unsure whether it has gone down the oesophagus as required, or whether it has ended up down the trachea. Checks. I have just noticed another book open on the table, this one having photographs and reproductions of xray images, rather than diagrams as in the other one. Alison and her colleagues had been using both, in conjunction with the xray images from the patient.

This sequence is noteworthy in a number of respects. First of all, in the surgeons' use of *numbers* of illustrations, or as Latour termed them 'cascades of representations'; a single picture it would seem, is not sufficient if others are also available. Secondly, in relation to the notion of 'enculturational learning'. Here, we see a direct example of such learning in action. Alison could not perform the operation using *only* the surgical manual, the anatomical atlas, the radiological atlas and (presumably) the radiographs. There were aspects of the procedure which could not be communicated by means of these words and pictures unaided. Ben's experience however enabled her to successfully carry out the operation. Thirdly, alongside the *actual* operation, its *virtual* counterpart was performed by surgeons who were seemingly peripheral to the procedure.

9.2.2 'Cascades of representations'....

During this operation, the anaesthetised animal was not draped at all, and neither was any hair removed from its head or face. It could be that this was considered unnecessary due to the fact that there was no incision involved. However, there was a good deal of drilling into bone going on, and if infection prevention is the expressed purpose, then pathogens can be introduced via this route equally as well as through an open wound. Another possible explanation might be that, since the area of concern was the interior of the animal's mouth, it was already sufficiently well delineated as a consequence of normal anatomy, rendering it unnecessary to further mark the area out from the rest of the body. The use of primary enhancement and reduction procedures for bodymapping purposes was therefore nonessential in this instance.

This was not the case however as far as *further* enhancement procedures were concerned. Alison consulted both a surgical manual and a radiological atlas, visually and verbally comparing the animal's injuries with those depicted in the textbooks. She had presumably also consulted the radiographs that had been taken of the cat's skull, although I did not see her do so, and neither were they available in the room at this point. This would seem to indicate that she had not found them particularly helpful, perhaps preferring to compare the actual injury (rather than the radiographic images of it) with textbook pictures which represented 'normal' anatomy (the 'goal state'), and others which showed methods by which the 'actual state' of the injured mouth could be manipulated so that it more closely resembled them.

Alison fixed on a method of effecting the repair with the aid of the textbooks, and after consultation with senior vet BMc. She was discussing her intentions with anyone available at this point, including myself and the nurse. She positioned the cat in lateral recumbency, so that it accorded with the direction from which the diagrams in the surgical text were drawn, and began her attempts at manipulating the bones into the correct position. However, although the procedure had looked fairly straightforward in the book, it quickly became obvious that this was not the case at all. It is evidently by no means as easy to judge the position of the roots of the carnassial teeth when they are embedded in the gum for instance, as a sectional drawing of the jaw would indicate. Neither was BMc's advice much help on this occasion, since his remarks had ostensibly been directed at the *pictures,* rather than to the actual injury.

9.2.3 Enculturational learning in action

Another problem was the comparatively large size of the available drill bits, which were intended for drilling into bones, rather than between the very small roots of a cat's teeth. Alison discarded them, and attempted to improvise using a needle instead. Ben's initial response, like that of BMc, to Alison's request for help was to look at the book. However, he soon rejected the method shown there, recalling instead an earlier, similar case (which may have been 'actual', or 'virtual') in which he had participated. He considered the (technically quite difficult) procedure to be a 'different kettle of fish' to the relatively straightforward account of it that was given in the textbook. Following Alison's initial failure to place the wire, Ben repositioned the cat so that it was lying on its back. Alison was disconcerted by this at first, since the pictures in the book clearly showed a cat laid upon its side. Even though Alison was following Ben's suggested adaptations to the method shown in the book, she still seemed to be dependent upon it at this stage.

Ben's manipulation of the animal proved to be helpful however, despite the fact that the cat's mouth was now viewed face-on, rather than in profile. At this point Alison apparently left the book, and concentrated instead upon the cat. Now she had abandoned the *virtual* operation, and with Ben's help (which took the form of both verbal advice and practical manipulations) she proceeded to perform the *actual* one, successfully wiring the jaw.

Alison's own use of language during this sequence was totally directed towards bodymapping and the practical considerations of carrying out the procedure. Like WW she was intolerant of interruptions, although as a young woman still in her twenties, her intolerance manifested itself rather differently[7]. Neither did she engage in off-task talk. Many of her verbalisations, certainly initially, were directed at anyone who would listen. There was a sense that she was using others present as a 'sounding board' to try out her ideas. This behaviour ceased however once she had turned from the book and its representations of an idealized jaw-wiring procedure to the actual case in hand.

9.2.4 *Actual* surgery and *virtual* surgery

As the procedure drew to a close, other surgeons (presumably in between operations of their own) wandered into the room, and just as we saw happening in operation 4, began to verbally rehearse possible alternative methods that Alison and Ben could have used to repair the fracture. Again, the pictures, rather than the injured cat itself (the injury, situated inside the small space of a cat's mouth, was after all visible only to Alison and Ben with some difficulty, and not at all to bystanders), were central to these discussions. This time however, both Alison and Ben involved themselves to some or other extent in these deliberations, explicitly justifying the method that they had chosen to use over the one shown in the book.

Alison, still occupied with the surgery, contented herself with showing the other female vet Lisa what she had done, and recounting to her the difficulties involved. Ben however carried these rhetorical processes further. Once the most difficult stage of the operation was over and Alison no longer required his assistance, he retrieved the radiographs of the cat's skull, which he then 'laid out' alongside the other pictorial representations of cats' jaws in the textbooks, justifying the (after all successful) method that he had chosen. These discussions continued with little further reference to Alison, who continued with the treatment of the cat.

Ben's use of both the visual representations of the cat's *actual* injured jaw, plus others of cats' jaws more generally in justifying his chosen method of repair, calls to mind Latour's (1986 pp 20-22) account of the advantages of what he termed *inscriptions* (or various types of simplified representations, including visual images) over and above the actual objects that they represent, for purposes of persuasion, or as he termed it, 'to mobilise allies'. According to Latour, such images are persuasive because they are mobile, immutable, presentable, readable and combinable with others (ibid p.7), unlike most objects in the natural world. Ben was observed to use them thus to demonstrate and to convince his colleagues of the effectiveness of his method. Like the artist respondents encountered in chapter 7, Ben used pictures for rhetorical, or persuasive purposes, although the persuasion here was to get others to see and accept his point of view, rather than to persuade clients to commission work.

9.3 Cruciate repair - operations 6, 7 and 8.

'Ruptured cranial cruciate ligaments in 66 dogs and 2 cats were replaced with mulhfilament polyester (Terylene) prostheses. The polyester was anchored distally through a hole in the tibial tuberosity and either passed 'over the top' of the lateral femoral condyle, or through combined femoral and tibial tunnels, or through a single tibial tunnel and 'over the top' of the lateral femoral condyle. The two 'over the top' methods gave better results, 64-70% of the joints becoming sound, whereas of the 25 joints treated by the other method, only 36% became sound.

Stead, A.C., Amis, A.A. and Campbell, J.R. (1991). *Journal of Small Animal Practice* 32, 448.

The cruciate ligaments cross over (hence their name) at the stifle (knee) joint, and hold together the bones of the upper and lower hindlimb thus preventing over-extension of the joint. The disruption of these ligaments gives rise to instability of the joint and hence severe lameness. This type of injury can arise as a result of strenuous exercise (just as in humans, where such disruption is a common sports injury), and although not life-threatening, is certainly crippling, rendering the affected limb useless unless the joint can be stabilised. Fig 12 below shows the stifle joint, and gives some idea of the delicate nature of this operation, especially in very small animals such as cats and small dog breeds. This section consists of three passages of field notes, (one fairly long, the other two shorter), which detail three instances of cruciate repair. Operations 6 and 7 were carried out on the same morning, one directly after the other by orthopaedic specialist IM. In the third example, the same procedure was carried out on another day by BMc, an experienced general practitioner.

IM's status as a 'specialist' is a formal one among his peers. Apart from the standard veterinary science degree, he had undertaken additional, advanced level training in orthopaedic surgery, and is officially listed as a referral surgeon for such cases by the BVA[8] and the RCVS[9]. By his own reckoning, IM carries out '80-100 times' more of these operations than would a vet in general practice. All three operations were carried out using different methods. Interestingly, that chosen by BMc appears to be far less straightforward than either of those used by IM. This section is interesting in that it shows further evidence of differences that

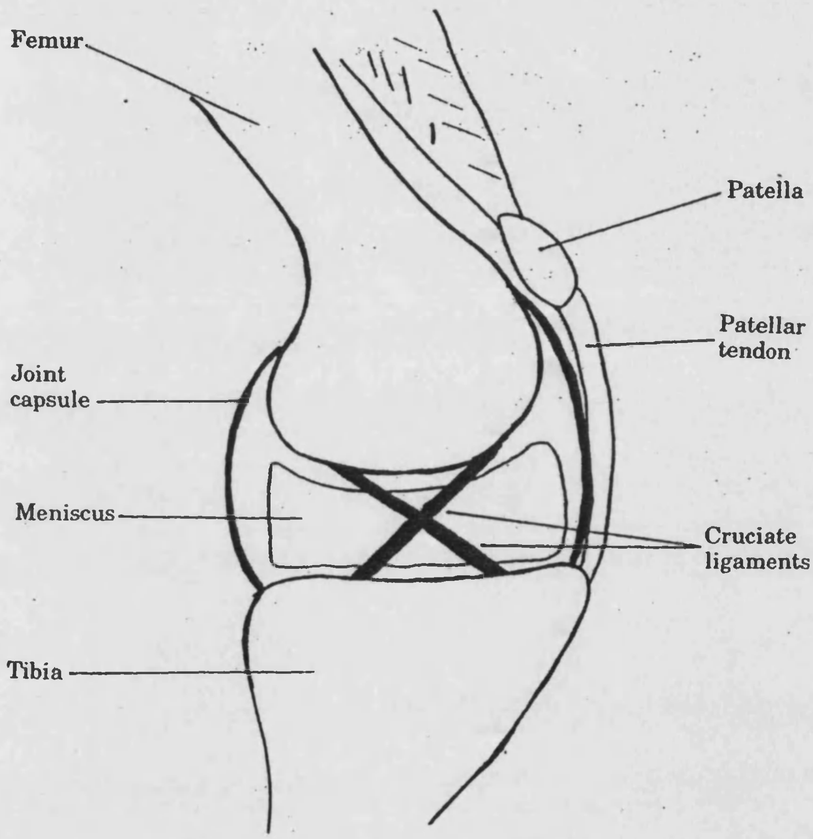


Fig. 12: Diagram to show the stifle joint , lateral (profile) view. Reproduced from *An Introduction to Veterinary Anatomy and Physiology*, by A.R. Michell and P.E. Watkins (1989), with permission of BSAVA.

exist between 'expert' practitioners, and those who are merely 'proficient' or 'competent' as regards the task under consideration, and also in relation to the use of enhancement and reduction procedures in complex surgery.

9.3.1 IM's first operation of the morning:

This operation (carried out upon a cat) was incidentally the first cruciate repair I observed, and at this point it was by no means obvious to me just how 'difficult' the procedure is considered to be. To operating surgeon IM, it was evidently a fairly routine, everyday operation. His colleagues showed little interest in the procedure, in stark contrast to the other surgeons present in the previous two sequences. It appeared that no-one at this practice bothered any longer to go in to watch IM's cruciate repair operations. They had presumably seen the procedure so many times before that, to them, it was no longer anything out of the ordinary. As one respondent put it, 1M was merely 'seeing his referrals'. It is interesting that there were apparently no 'virtual' operations performed alongside 'expert' IM's.

Later that week, IM however *did* have a spectator for one of these operations (apart that is, from myself and a nurse). This visitor was the general practitioner who had referred this particular patient to him. Unlike the veterinary surgeon spectators observed elsewhere, this surgeon did not look for pictures of the operation. This was just as well, since IM only used radiographs. Neither did she verbally rehearse alternative methods of performing the surgery (although it is possible that she may have done so later, in conversation with colleagues elsewhere). She merely watched quietly, except for asking the occasional question, apparently content to learn from watching the specialist at work. This may have been linked to the fact of her being 'alone' at the scene, apart from the nurse and myself (who were not part of the form-of-life of veterinary surgeons), and IM himself.

Like RH whom we met previously, IM appeared to enjoy (rather than merely tolerate) the company of others whilst he was operating. He chatted about general matters as he scrubbed up. He was the only surgeon observed (apart from James) who both meticulously observed the 'scrubbing up' ritual, and also wore special, designated clothing for operating, including a cap, mask and gloves. He seemed however much more at home in this garb than had James. Goffman (1961) discussed the 'presentation of self' by surgeons, and following on from this analysis, it could be surmised that, while James appeared eager to present himself as part of a 'body' of qualified and competent surgeons, in IM's case these practices served quite a different purpose. Since most of the time experienced surgeons paid scant attention to these preparations, their unqualified observance functioned to set him apart in some respects from this 'body', and in doing so, to mark him out as someone outside of this 'normal', or 'ordinary' experienced veterinary form-of-life. It is interesting incidentally, that this was also the only occasion on which *I* was asked to put on a surgical gown over my street clothes *'because orthopaedic operations pose a risk of serious infection'.* I was not however asked to do this when observing other surgeons performing orthopaedic surgery.

IM draped the cat's small body carefully, leaving just the stifle joint visible, creating a tiny window through which he would operate. He then prepared his instruments, continuing to chat whilst he did so. The nurse (Alice) occupied herself with monitoring the anaesthetic and various other tasks, occasionally joining in the conversation. Still chatting, IM then examined the damaged leg. At this point there were a number of interruptions. About 15-20 minutes elapsed. IM's surgery was characterised by frequent interruptions, which (in contrast to the surgeons featured earlier) he dealt with unfazed. On each occasion, once the enquirer had left, he immediately returned to task, behaving for all the world as if the interruption had simply not happened.

'I think we may be in luck, that it may be just the cruciates that have gone... but they've gone in a bad way... and it really is just a question of just getting in there and seeing what we've got... but sometimes we've got these collaterals that go into the bargain.., cats are very fond of disrupting as many as they can at one time' (makes first incision at this point). *'Is everything OK Alice?* (to nurse). *'Another problem is, that they go climbing somewhere, they fall and get the foot caught in holes in fences and things like that, and all the weight lands on that stfle, and it just rips...'*

At this point, the nurse asked which needle he wanted, and someone else came in with another query. This happened on some three more occasions. In between *times, he continued to talk, among other things, such as the organisation of his business, how he could improve efficiency, and research methods in social science and veterinary science respectively! In the middle of asking whether I had to 'abandon all preconceptions beforehand', he returned to task. 'What have you done pussycat ? **That's** just a **blood** clot.... ' He then proceeded to talk about the prognosis for this cat, and cats in general:*

*'Cats heal incredibly well, from all sorts of things. There is a joke in veterinary orthopaedic circles that if you take two halves of a broken cat and leave them lying about in the same room, they will join up again.... You have to hope that it will cope with the lifestyle that a cat's going to give it...and, **err, that's intact but slack*** (collateral ligament)..,***but the cruciate 's obviously gone.*** *If you can only hold it in place, usually they recover quite well. Alison, I want a PDS suture, and a 19 gauge needle.... ' IM was preparing to stitch over the top of the stifle joint to hold it in place. At this point, I asked IM whether it was possible to simply stitch the cruciate ligaments back together again. He replied:*

'No, it's detached and it's frayed, it just sort of disintegrates really... very, very occasionally, but to be quite honest I've never come across it yet.. .just occasionally I'm told you actually get one that pulls off with a lump of bone... then you simply screw that lump of bone back. It's in all the books, but I've never seen it... Theoretically, it's possible to put an implant in, in the middle of the joint, but by the time you've done that...'

Self : 'So you just sort of stitch through the joint'?

IM: *'What I actually do now... there are a variety of techniques. ..at last count about 160 different ways of repairing cruciates...which is basically a way of saying that maybe nobody has got it right yet... Once anybody's got a firm, guaranteed technique, we'll er, do that! Umm, so I think what we're rapidly coming to is at the moment the techniques we have, basically you go and you stir the joint up, and when the dust settles and the scar tissue settles down, it will be stable... and how much we actually... as we try and get more scientific about it, as you get increasingly complicated techniques of repair and so on... are we really doing more than just jiggering the joint up and waiting for the scar tissue to take over? I was talking to somebody yesterday, there's an American who did a subject evaluation of different cruciate repair techniques, I mean ten over the tops, and ten extra-capsulars, and in ten controls, he just opened up the joint and* *stitched it up again. And those ten did better than anything. So you know, arguably, all we're doing is opening it up to make meniscal damage, stitch it up and the fibrosis will take care of it. ..so I've tended to back off a little and go for less invasive surgeries.., they seem to give me just as good a result, they're quicker, and you know, the less you muck about in there, the less risk of infection and so forth.* ***..Right then, that feels more like a joint. I think we'll stitch*** *that up. If I were doing this op in dogs, I would use stainless steel* (wire to stabilise the joint) *but err, the wire that is equivalent for cats is really thin, it would just fracture as soon as you started to tighten it up.... we know that the wire will break; what you hope for is that it will provide adequate support for long enough... before it breaks. If a dog keeps hold of it for three months, by which time it should heal... But I would like to consider... I don't know if I would dare try it... using a heavy gauge version of this* (suture) *instead of wire in dogs, so that it would dissolve and be gone... the difficulty is making sure you can get it tight enough. The advantage of wire is that you can just give it a little turn, a little turn, and if you need to, turn it a bit more....'*

During this 'difficult' operation, IM apparently switched effortlessly between on-task and off-task talk, tolerating numerous interruptions in a good-natured fashion. All the indications were that, for him, this procedure was not especially 'hard' at all, any more so than was a normal spay operation for RH whom we met in chapter 8. Even the strictly on-task talk (ie that about cruciate repair in cats) was not confined to this particular operation, but rather tended to range around the topic of cruciate operations (and cats' propensity for injuring themselves in this way) in general.

I have highlighted three very short instances of IM's 'bodymapping' talk in bold type. The first two are related to the identification of abnormalities or otherwise in the tissues concerned (ie, the presence of the blood clot, which he removed, and his estimation of the condition of the intact collateral and damaged cruciate ligaments). The third instance refers to his satisfaction with the result. Because the joint had been successfully stabilised, the leg now felt 'normal'. The goal state had been achieved. For IM, it would appear that the cat's actual skeletal anatomy had become 'merged' with representations of the 'normal' feline skeleton (Hirschauer 1991).

Other interesting features in relation to this exerpt were firstly IM' s reference to the use of humour in the veterinary orthopaedic form-of-life, secondly the way in which he (like Ben whom we encountered earlier), referred to differences that exist between 'textbook accounts' and actual incidences of injuries and operations, and thirdly the way in which he was observed to 'think aloud' about alternative methods of cruciate repair, apparently prompted by my question.

9.3.1.1 Use of humour

IM referred to the existence of 'a joke in veterinary orthopaedic circles' concerning the ability of cats to recover from serious injury. 'Veterinary orthopaedic circles' implies membership of a different form-of-life from that of 'ordinary' veterinary surgeons. Referral surgeons such as IM are acknowledged by their peers to be experts in their field, and to work at the very forefront of what can be accomplished in veterinary medicine. In respect of their specialism, and the accompanying 'specialist' status, it can be surmised that they bear more resemblance than other vets to consultant surgeons in 'human' medicine. The use of humour by surgeons has been discussed elsewhere (eg, Wilson 1954; Goffman 1961; Katz 1981). It is argued here that such strategies function both to help relieve tension implicit in working at the forefront of one one's discipline (Wilson 1954; Katz 1981), and also in relation to Goffman's (1961, p.109) contention that such behaviour formed part of the 'presentation of self' of the chief surgeons that he observed, a display of their 'role distance' from their subordinates, and a subtle means of reinforcing this.

Links could be drawn here with the particular attention paid by IM to self-preparation prior to surgery. IM, like novice surgeon James (but unlike other experienced surgeons observed), prepared himself in the approved 'textbook' manner for operating. I suggested that this may have served in part to distinguish him, as a specialist, from the 'body' of ordinary veterinary surgeons. His remarks above also set him apart in a sense, from this other group.

9.3.1.2 'It's in all the books, *but I've never seen it...*'

IM, like Ben previously, referred to the differences and discrepancies that exist between the 'idealised' injuries and operations depicted and described in textbooks, and his actual, personal experiences of these injuries and operations. I did not see IM use a textbook whilst he was operating. However, there was no evidence that he scorned such literature; on the contrary, he was very well read on his subject, and had himself contributed articles to veterinary journals. His comment above hints at these differences that exist between 'book knowledge' and 'experience knowledge', or 'knowing that' something is (at least theoretically) possible, and 'knowing how' to do it in actual practice.

There are a number of possible reasons for the existence of these differences. For example, we have seen that not all aspects of either complex tasks, or their skilled performance can be stated. Also, as Lucy Suchman (1987) argued, every action is a situated action'. Following on from this, there is no such thing as a 'general' context in which such an action takes place. Each operation for example, forms a specific context which, whilst it has similarities to other operations of the same type, also retains certain, unique features not present in any other incidence, and so 'hidden' in the generalisation that inevitably accompanies written accounts.

9.3.1.3 'Thinking aloud'

IM, like the surgeons who were *observing* the compound fracture and hard palate repairs discussed earlier in this chapter (as opposed to those who were actually *performing* these procedures), verbally rehearsed possible alternative methods to that used, (in this instance the use of alternative materials to stabilise the joint). In IM's case however, he himself was the operating surgeon, rather than being peripheral to the procedure. This too I feel, is linked to the fact that he works at the forefront of his discipline. Some of the operations that he carries out are therefore 'experimental' or 'hypothetical' in nature, in the sense that they may not previously have been performed (or at least performed in quite *that* way), either by himself, or by anyone else.

Incidentally, in later conversations about cruciate operations, experienced surgeons RH and BMc expressed surprise at IM's customary use of stainless steel wire for cruciate repair in dogs. This indicates that this method (which was routinely used by IM as shown below) was probably not a standard 'textbook' method for carrying out this procedure. Therefore, just as 'ordinary' vets may verbally 'try out' or enact virtually procedures that are new to *them,* expert practitioners such as IM may similarly enact those which are new to veterinary science itself.

<u>9.3.2: IM's second operation of the morning (operation 7).</u>

On commencing this operation (which was carried out upon a dog this time), IM had spoken of his intention to use the same 'over the top' technique as he had used for the previous operation, (except for the use of a different material to stabilize the joint). However, once he had opened up the joint, it became evident that this patient had disrupted the collateral ligament in addition to the cruciates. The collateral ligament (which runs down the lateral aspect of the joint) was not broken however, but had become detached with a fragment of bone. IM quickly reattached the bone fragment (with the ligament attached) to the periosteum with a small screw. He then proceeded (in between the usual interruptions) to effect the cruciate repair. I noticed at this point that he was using a different suturing technique, stitching through the joint from one side to the other instead of over the top of the knee. When I asked him why he had decided to do this, he replied that he didn't want to follow the normal procedure because of the complication to the case caused by the detached collateral ligament. He spoke of having to make decisions like this on the spur of the moment:

'There's a world of difference between what you see in the classroom and what you see on the table.... narrowing down the list of possibilities when you actually have to make a decision, committing yourself. It's one of the difficult things to learn, decision making....'

IM had made the decision to use an alternative technique because of the necessity to repair the disruption to the collateral, as well as the cruciate ligaments As a consequence of this unforeseen injury (literally unforeseen, since ligaments show up only poorly if at all on radiographs), the necessary repair to the collateral ligament would have 'got in the way' had he used his standard technique. He did so apparently automatically, without remark, and in the midst of the interruptions that characteristically accompanied his work. When I asked him about it, he again reflected upon the differences that exist between 'book knowledge' and actual experience. He highlighted the difficulties inherent in learning to make decisions based upon what is actually present, rather than theoretical representations of what *might* be there. Again, this reflects characteristics of 'expert' practitioners already discussed.

IM's reference to the difficulties of learning to make decisions in surgery calls to mind a remark made by one of Cassell 's (1987) surgeon respondents, that there is a permanent need for decision making during operations, which can be compared to a cyclist's need to keep in motion. For IM it would appear that this decision making ability apparently developed alongside (and drew upon) his surgeon's experience knowledge. Blois (1980) addressed questions relating to how much of clinical judgement is computable, and whether thought itself is governed by rules. Like computers, novice practitioners seem to need to follow sets of specified rules to order their conduct in a given situation. As an individual gains in experience however, these rules are put aside in favour of other strategies. IM provides an example of an 'expert' who has abandoned 'the rules' (such as those encoded in textbook accounts of orthopaedic surgical procedures), allowing creative solutions; innovation!

9.3.3 An example from a non-specialist (operation 8)

This final example was observed some fifteen months after my first period of observation which had taken place at the orthopaedic referral practice, and it was in fact the first time since then that I had seen this procedure carried out. During the whole of the intervening period, I had been spending at least two or three days per week in veterinary practices, observing surgery, and had not again seen this procedure. This gives some idea of the unusual nature of this operation, and how singular was the situation in my first placement, where I had seen ten or more of these operations carried out over a two week period. They had seemed in fact to make up the bulk of the referral surgery carried out by IM, in the same sort of way as spays made up the bulk of the operations carried out by experienced general surgeon RH during the observation period. In this instance BMc was the operating surgeon.

BMc operating on a cruciate case in the other room. The dog is in a cradle in dorsal recumbency, the leg shaved, and tied to the table. BMc uses a different method to IM and it takes much longer, and seems to be more difficult (or perhaps it is just that he hasn't done so many?). The animal is draped so that only the site of the stifle joint is visible. Says to one of the other vets that he is going to do 'an over-the -top'. I am interested, because I had seen IM do this procedure. But this method is different. BMc explains that he is using a bit of fascia tissue from the side of the animal's knee, 'sort of pulling it through the path where the ligament goes'. This tissue is attached to suture material, to aid this pulling through process, which is fiddly. IM's drilling and wiring is a lot quicker. But eventually he finishes the procedure, starts to suture. I ask about when it is necessary to concentrate, and when it doesn't matter so much when interruptions happen. He spoke of 'critical stages' during an op, (more problematic if interruptions happen then) when you sometimes switch off the radio, and close the door to shut out some of the hubbub.

BMc used a much more complicated 'textbook' cruciate repair method, and perhaps as a consequence of this, took more than twice as long to carry out the operation than had IM. He had the textbook concerned on hand, and also the radiographs of the damaged leg. As WW had done previously, he initially consulted the book, and then largely seemed to ignore it. He did however consult the radiographs at frequent intervals, probably to reassure himself of the path of the cruciate ligaments, about which he expressed concern. IM, by way of contrast, ignored this path, passing his suture through the joint at whichever point seemed appropriate in the light of the injury encountered. IM avoided the use of the slimy and difficult to handle fascia tissue that BMc dissected from another part of the dog's leg for securing the joint, choosing instead stainless steel wire that was much easier to manipulate and allowed a great deal of control in relation to tension.

This seems to be the major difference between the experienced and less experienced surgeons encountered in this study, that with greater experience, far less attention is paid to certain details that seem very important to beginners. Experts seemingly possess the ability to simplify complex procedures in such a way as to make them appear far less complex. This simplification is encoded not only in their attitude towards the procedure (which obviously becomes less fraught with increasing experience), but also in the actual methods chosen to carry it out. When experts make a procedure look easy this is not merely an artefact of their more practised manipulations, but also of their choosing more straightforward methods in the first place, and being able to make short cuts, bypassing some of the more difficult manoeuvres altogether.

Although he did not carry out cruciate repair operations often, this was certainly not the first time that BMc had done so. He was an experienced practitioner who had a local reputation amongst other vets and animal owners as a 'good surgeon' who could successfully carry out most procedures, including those regarded as 'difficult' by peers. However, in comparison with IM, be proceeded on this occasion in the rule-bound fashion characteristic of practitioners at much lower skill levels.

9.4 Discussion and conclusions

Main concerns raised in this chapter include *further enhancement procedures* (which may be visual or verbal, direct or indirect, although as usual these are by no means exclusive categories), and their use by different groups of surgeons in performing actual and virtual operations. Continuing on from matters addressed in chapter 8, the differences that exist in novices' and experts' approaches to a task, and between textbook accounts and actual practice are further highlighted. I began by outlining ways in which the orthopaedic operations described here differ from the more routine spays discussed in the previous chapter, whilst at the same time retaining certain common characteristics. For example, the pre-operative preparations undertaken are similar (or at least their textbook descriptions are), and the operations proceed through the same stages from beginning to end, as described in the chapter 1.

In chapter 8, considerable attention was paid to surgeons' uses of what I have called **primary enhancement and reduction procedures** - pre-operative positioning, shaving, draping and so on - for the initial mapping of the internal body. A good deal of variation was found in the extent to which these procedures were applied in the case of routine spay operations, and this variation led me to speculate that they served this other purpose, quite apart from their stated one of infection prevention. For the 'harder' orthopaedic operations described here however, considerably less variation in primary enhancement and reduction measures was encountered. For these operations it would seem, these procedures were for some or other reason of some importance to all surgeons concerned. All of the orthopaedic patients observed except for the hard-palate repair cat were prepared conscientiously, and in addition this preparation was often done either in part or wholly by the surgeon him- or her-self, rather than by an assisting nurse.

For orthopaedic operations (in contrast with spays), the acknowledged 'expert' was just as scrupulous in these preparations as less experienced surgeons. The particular vulnerability of orthopaedic operations to infection is not disputed. Both the veterinary text quoted at the beginning of the section devoted to compound fractures, and the testimony of the orthopaedic specialist provide evidence for this. However, I feel that, although the extra risk of infection is certainly an issue here, this neither negates the conclusions of chapter 8, nor precludes the possibility of yet another possible, additional purpose for these preparations.

A possible clue lies in the differential preparations of the *surgeons'* own bodies, linked by Hirschauer (1991) with the preparation of *patient-bodies* as important in initially making possible the mapping of the body. Orthopaedic consultant IM prepared himself just as assiduously (though, it must be said, less self-consciously) as had newly qualified James. In contrast to these two examples, the personal preparations of the other surgeons encountered were scarcely any more thorough for orthopaedic surgery than for a routine spay operation. It is argued here however that these self-preparation rituals as performed by James and by IM, served quite different (indeed opposite) purposes. For James, enacting the rituals into which he had recently been initiated may have served also to characterise him as a now fully-fledged member of the veterinary surgeon form-of-life. In IM's case however, (for whom this was obviously unnecessary), it perhaps served rather to *distinguish* him from the body of 'ordinary' experienced practitioners, who seemed to trouble themselves far less with these preparations. It is possible therefore that the scrupulous preparations of the patient functioned to distinguish these 'difficult' operations (which tended to be carried out by experienced, senior surgeons), from more mundane procedures such as might be performed by *any* qualified vet, however inexperienced.

Notwithstanding the importance of primary enhancement and reduction procedures for whichever purpose, a major focus here is on further **enhancement procedures,** defined as those procedures enacted for the purpose of further elucidating and differentiating internal body organs and tissues (ie, once surgery is underway, rather than prior to its commencement). As we saw in operation 1, further enhancement procedures can take a direct form, that is, applied directly to the patient-body. This was demonstrated by James' use of gauze swabs to conceal abdominal organs not of immediate interest to the spay operation upon which he was engaged, thereby presumably 'enhancing' for him those of immediate concern.

Such procedures can also be indirect, that is, not applied to the patient-body itself, but used more in the sense of aiding the surgeon's thinking about it. RH used *language* as a further enhancement procedure, *talking* his way through the identification and differentiation of abnormal organs in operation 3. Pinch et al (1996, 1997) also observed a similar use of language in respect of veterinary surgery, and we see here yet another example in relation to expert orthopaedic surgeon IM, who switched between off-task talk and verbal bodymapping as he carried out cruciate repair operations. In operation 5, the young vet Alison was seen to use language in combination with visual representations in her initial deliberations as to the most effective method of repairing the cat's hard palate, using others present (including non-vets) as a 'sounding board' to rehearse her ideas.

This brings us to discussion of 'indirect' further enhancement procedures of a visual nature. I include within this blanket term radiographs, and also illustrations in surgical manuals, anatomical atlases and radiological atlases. These images were seen to be used not only by those surgeons directly concerned with the operation that was being carried out, but also by others who were peripheral to the procedure, but were in effect participating in the operation vicariously. It is argued here that this participation in 'virtual' operations which takes place alongside 'actual' ones, is not a trivial matter, but crucially important in the development of surgical expertise. As well as 'collaborating' in the performance of virtual operations, surgeons were observed to do so in *actual* ones. In this way, further enhancement procedures of a verbal and a visual nature were seen to be used together.

When for some reason a vet required assistance, whether of an advisory nature, or purely manipulative, they would if possible co-opt another to help. Social interaction thereby allowed difficult tasks to be more readily successfully performed, as well as being critical for learning. It would appear that surgeons' learning is accomplished by means of collaborating with others in actual and virtual operations. Such collaborations therefore appear to be a strategy whereby bodymapping becomes possible for surgeons.

It is time now to draw together the threads of inference that have been extracted from all of these observations.

NOTES

1. The cruciate ligaments cross over behind the knee joint, holding the long bones of the upper and lower hindlimb together. See Fig 12.

2 'Harder' as in 'more difficult'.

3 The bones of the roof of the mouth.

4 Lying on its side.

5 The wrist, as it is known in humans.

6 Road traffic accident.

7 Alison expressed her intolerance of interruptions by means of humour and laughter, passing it off as a joke. Compare this with the terse reaction of (the normally genial) senior vet WW. It is contended here that as a young woman, Alison would see (and quite possibly, others would see also) such a reaction as inappropriate. See Hunter (2000) for discussion of women and power.

8 British Veterinary Association

9 Royal College of Veterinary Surgeons

CHAPTER 10: DISCUSSION AND CONCLUSIONS

'Thus, the practice of operating appears to be a versatile craft. It resembles building or carpentry in the way bones are sawed, drilled, chiselled and screwed together; tailoring where skin and tissue of different consistency are cut apart and sewn together; the work of sailors, when various knots are tied; and a butcher's trade, when muscles and innards are carved up...'
Stefan Hirschauer 1991, p.300.

10.1 Introduction

We have now reached the point where it is necessary to tie together loose ends (of which there are several), identify the weaknesses and inadequacies of this study, (of which there are also several), and notwithstanding these, address more or less directly the aims and research question stated earlier. It is also necessary that I highlight other points of interest that have arisen from the data, and make suggestions for further research. Finally, I consider ways in which the issues raised by this study may be more widely applicable.

The research question itself, 'How do surgeons map the body during operations?' is on closer inspection seen to be composed of a number of smaller, related questions, concerned with the uses that surgeons make of 2D representations of their patients' 3D bodies, the ways in which they relate their actual experience of bodies to textbook accounts and representations of them, the ways they mediate uncertainty, and the ways in which all of these things change as they gain in experience. I will examine these 'sub-questions' in turn, mainly in respect of fieldwork data relating to surgeons, but drawing upon sculpture data too, where this can contribute some small insights. I begin however, by discussing the themes of *narrativity* and (linked to this) *categorisation,* and problems that have arisen in relation to them. I next move on to consider some of the major criticisms that could be made of this study, notably in relation to methodology and objectivity.

10.2 Absolute categories or fuzzy boundaries?

I expressed early on a desire and intention to avoid the constraints that narrative imposes, via the use of alternative notational forms (alternative that is, to the use of text alone). I speculated that using graphics alongside text, in the tradition of 'visual languages' (Rudwick 1976) would help to overcome these constraints. However, since I have experienced *anyway* a great deal of difficulty with the narrative ordering of this thesis, (which was necessary however because otherwise it would not *be* a thesis, but something else instead), I suspect that I have not entirely succeeded in this aim. We have seen how the narratives that we construct in order to make sense of, and communicate our experiences, tend to render some aspects of them tacit. This is due to the necessity to impose a linear sequence on to complex events and topics which do not necessarily occur in a linear way, one part following another in an orderly fashion. This however is how narrative constructs them. Writing a PhD thesis, like performing a surgical operation or carving a sculpture, is one such complex activity, (ie, making a report of complex activities), and much of the complexity tends to disappear in the telling, resulting in what I feel is a somewhat superficial account that lacks fine detail. This counts not only for the processes of operating, or carving, but also for that of writing about these activities. This line of thinking can only eventually result in infinite regress. It is however, the key to the differences that have been found to exist between actual practice, and textbook accounts of it, and is an issue that has proved problematic also in such fields as Expert Systems research, where experts have similarly been unable to specify all parts of their knowledge.

The associated necessity to categorise, categories themselves, and the boundaries that exist between them, are also seemingly inescapable. The 'knowing' and 'seeing', and 'seeing *as*' and 'seeing *that*' categories are particularly salient to this research, and were the cause of initial problems encountered in organising the topics of the literature review into separate sections and chapters. Many of these topics would not sit easily under either 'knowing' or 'seeing' headings, but seemed to be relevant to both. This made writing these sections much more difficult than I had anticipated; so much so, in fact, that I am surprised that I have so infrequently come across any reference to this problem in other accounts. This it would appear, is one of the aspects that remain 'hidden' in many accounts. I have attempted to 'open it up' for discussion by recourse to a reflexive approach.

Splitting 'knowing' from 'seeing', or for that matter 'seeing as' from 'seeing that' not only seems arbitrary, but appears to connive at dualism even in the very act of questioning it. As a result many items were moved from one chapter to another, in some cases several times. Even now, I feel that there are topics that sit uncomfortably where they are, not necessarily because they do not 'belong there', but because they also belong in several other places!

Immediately after the literature review was completed, new problems arose when it came to discussing my research methods. This I realise is because *thinking* about research methods (or for that matter about *any* activity which we have carried out in the past) is always problematic when we attempt to subsume what we have actually done or experienced into some sort of narrative order. Certain important aspects seem to be hidden by this process. For example, as I pointed out previously, the data collection, analysis and writing stages of this research were not easily separable; I found it very difficult to 'list' them in the order in which they occurred, for the simple reason that they often occurred together, all at the same time. I do not think that this state of affairs is peculiar to this work, but as Paul Atkinson (1990) has intimated, is probably common to all research, or certainly to all qualitative research.

The data collection phase for example, involved a good measure of elementary analysis, in selecting which events to observe (since it was not possible to observe *everything),* in judging which particular 'aspects of these aspects' to record, whom to engage in conversation, and what questions to ask them! It also involved the *writing down* of field notes, which was no small matter, since they would become the basis for the *writing up* of this final report. The analysis and writing stages likewise, each involved elements of both of the other phases. Analysis often (or perhaps usually) shows up gaps in the data, thus raising new questions, and in the early stages at least, this often sends the researcher back into the field to try to discover what she has missed. This stage, in my experience, is problematic because one is always being tempted back into the field to try to find out more. Thus fieldwork is seductive, and attempts at analysis render it more so. Writing too, is not an activity that is in reality easy to separate off from other research activities. As we saw above, it forms part of the work of data collection, but neither is it entirely separable from analysis. For me, much of the 'real' work of analysis took place through the actual writing itself, despite having spent several months attempting to order field notes into categories in the accepted tradition of 'qualitative analysis'! Thus we have travelled a tortuous route from data collection to analysis to writing and back again, often in a zig-zag sort of fashion.

Despite its inherent difficulties however, categorisation may, as Eleanor Rosch has stated, be essential for ordering our thinking. Evidence from veterinary surgeon respondents seemed to indicate this, by the ways in which they categorised the operations that they carried out. This seems important, since the way they classified these procedures appeared to affect the ways in which they thought about them, and approached them. However, as I soon discovered, categories themselves can be thought about in different ways, for example, as absolute, watertight entities, or rather more flexibly. Experienced surgeon BM referred to differences that exist for example between 'emergency' and 'non-emergency' surgery. However, when I attempted to apply these categories rigidly, as headings for 'analysis' purposes, I became aware that this was not at all what BM intended. It became apparent that 'emergencies' are themselves subject to classification. Thus BM's 'emergency' and 'non-emergency' categories were loose ones, *heuristic* in nature. For most purposes (his purposes) they worked perfectly well, as a tool for classifying surgical operations in the veterinary form-of-life.

In this instance (of my trying to use them *algorithmically,* as an analytical tool) though, they soon revealed themselves to be inadequate. By reworking these categories, essentially by subdividing the 'emergencies' category much more precisely, I was eventually able to make this classification work as a tool for analysis, at least for the examples encountered in this thesis. It is however almost inevitable that if sufficient, further surgical operations were sampled, we would eventually come up against other examples which did not quite fit even into these newer, and more precise categories.

One explanation for this is that experts and novices appear to use categories rather differently. Novices seem to use them like algorithms, and experts to use them more heuristically. This in itself is an interesting 'finding', and may offer a clue as to why experts are often not the best teachers for novices, and also incidentally why many 'expert systems' have been shown to be of use only to other experts. To communicate complex information, it must be first broken down into less complex units, and this implies categorisation in some shape or form. If novices and experts use, and think about categories in different ways, it follows that experts' explanations may lead to confusion for beginners. As a novice classifier of surgical operations, I attempted to apply a method of classification that had been suggested by an expert. Once I started to use it in attempts to classify surgery for my own purposes of analysis however, it soon became evident that it was inadequate because it was not sufficiently inclusive to work for *every* case described.

As we see from this simple example, categories can often be specified in a more inclusive way. With the benefit of this small amount of experience of operation-classifying, this is what I eventually did. Novices require that their categories be absolutely reliable and inclusive, and become confused when some object or occurrence fails for some or other reason to fit into them. With experience however, other factors come into consideration, and this rigidity becomes less important. This allows the practitioner (who may be a surgeon, or a researcher) to become more flexible in his or her approach. In fact, as Dreyfus and Dreyfus (1986) pointed out, this rigidity *must* be tempered, or progress to more advanced stages in the acquisition of the particular skill in question will not be possible. In my own case, early difficulties with assigning discussion of previous research under particular headings may simply have signified novice behaviour in relation to social research. An alternative explanation (since this research is 'unconventional' in a number of respects) is that this uncertainty results from the fact that the research itself inhabits a 'fuzzy boundary' of its own, between what has been done before and what has not. Perhaps again, neither explanation is on its own sufficient, but both beg consideration. An uneasy alliance!

10.3 'Subjects' and objectivity...

Apart from problems with narrative sequencing, and with the categorisation of objects and events that is necessary to form the narrative structure (as if this were not enough!), this work has other inherent problems. For example, it could quite justifiably be criticised for being overly 'subjective', (though I make no claim to 'objectivity'). Objectivity in research - any research - is in any case an unachievable ideal, and (I feel) an over-rated one. My methods, particularly in respect of participant observation and dabbling with introspectionism, are particularly unsuited to such claims. I was unsure at the outset whether it was in fact possible to research this sort of topic at all, outside of the controlled conditions of the psychology laboratory.

Novel topics and research contexts are all very well, but they do require a certain amount of departure from 'traditional' ways of thinking about research, and from 'traditional' methodologies too. I did not find this aspect at all easy, particularly since my early training was in the field of biology, which is rather rigid (at least as far as research methodology and the required style of writing is concerned). I experienced the feeling at times that I was experimenting at the boundaries of accepted methods, since all of the usual ones seemed unavailable, inadequate, or both. Quite apart from methods, mixing surgeons and sculptors as research participants is hardly indicative either of a conventional approach. There is undoubtedly some tension here, and plenty of room for criticism. However, one of the requirements of a PhD thesis, is that it is 'original'. With a novel research context, a novel combination of respondents and novel methods, this is one aspect at least which is hard to criticise. To offer some degree of justification for an approach which I still consider was *necessarily* unconventional, it is time now to address the research question, to show the insights that this approach can contribute to our understanding of practical skills.

10.4 Mapping surgeons' mapping the body...

As I pointed out earlier, my initial research question can usefully be broken down into a number of smaller 'sub-questions'. I will therefore deal with these in turn, bearing in mind that all, as usual are linked, and this particular categorisation should be seen as *heuristic* in nature, rather than the following sub-sections be considered as exclusive, or *algorithmic* categories.

10.4.1 What uses do surgeons make of 2D representations of their patients' 3D bodies?

As we saw in chapter 7, sculptor respondents were observed to make certain uses of pictures (or reported these uses), in the construction of three-dimensional artefacts. They used them for example, as sources of ideas, for solving problems (particularly problems relating to dimensionality, where *numbers* of pictures, as opposed to single ones, were seen to be more useful), and as rhetorical devices. Certain other possible uses however were rejected, or shown to be problematic if they were used. Examples which fall into the latter category include their use (somewhat surprisingly, I felt) as 'blueprints' for planning work, or as models to copy directly. What then of surgeons? The data clearly show that surgeon respondents also used pictures (anatomical pictures and radiographs) as aids to surgery. But what were these uses however, and how do they compare with those of sculptors?

Firstly, the surgeons did not *always* use pictures. Arguably, neither do sculptors, although the limited data available at this point did indicate that four very different respondents all made some or other use of them on some occasions. However, I did not for example, observe a single surgeon use pictures during a routine spay operation (although several *were* observed to use other bodymapping aids which we will discuss later). During orthopaedic operations in contrast, all respondents involved used them, although the numbers and types used, and the extent to which they were used, were seen to vary along with the type of operation, the people present, and the amount of prior experience that the operating surgeon had accrued of performing it.

Interestingly, surgeons' uses of pictures did appear largely to mirror those of sculptors. They were likely to use them for sources of ideas, for example, for suitable surgical techniques to employ in a given case, for solving problems (in relation to anatomical ambiguities, or surgical techniques again), and for rhetorical purposes, in persuading other surgeons of the efficacy of their methods. They proved inadequate or problematic however, as 'blueprints' of the body (one reason for this being presumably because actual bodies tend to vary in ways that anatomical pictures of them do not). Also, and linked to this, it seemed to cause great problems if surgeons attempted to 'copy' exactly the operations shown in surgical manuals, as Alison found in her initial attempts to repair the cat's disunited hard palate in operation 5. Again, like the sculptors, the surgeons appeared in general to prefer *numbers* of visual representations to single ones if they were available. They also selected pictures from a range of sources rather than from a single source where possible. This recalls the dynamic construction of representations by scientists described in Lynch and Woolgar (1990), and it is surmised that by this use of multiple 2D representations which they juxtaposed together, both sets of participants were able to 'build up' a composite picture which more approached the 3D reality with which they worked, but was at the same time simplified in important respects.

10.4.2 In what ways do surgeons relate their actual experience of bodies to textbook accounts and representations of them?

It cannot be denied that clear differences exist between textbook accounts of a practice and the actual practice itself. For example, following, or attempting to follow textbook instructions 'to the letter' when carrying out an unfamiliar procedure almost invariably leads to problems. It is therefore seen to be difficult to apply textbook knowledge unmodified to actual practice. This can be easily observed in commonplace situations, for example when children are learning to cook at home. Even where they seem to possess sufficient skills, for example to read the recipe and measure the required ingredients, they experience difficulty in following the instructions in recipes, and often need to call upon a parent or more experienced sibling to provide explanation of these, and sometimes practical demonstrations also. Thus certain 'informal' aspects of cookery-knowledge require to be conveyed to the novice cook by means other than recipes!

There are likewise 'formal' and 'informal' aspects to veterinary surgical knowledge. The informal ones may be difficult to express in words, and so tend to be left out of textbook accounts. Some informal aspects may be expressed as heuristics, or 'rules of thumb'. These cannot however be guaranteed to work on every occasion, and there may be different ones in circulation for the same situation, which can lead to confusion, especially for novices. It is necessary therefore to think about other ways of conveying information apart from sets of propositional instructions, and informal (and sometimes unreliable) heuristics.

Unlike text or spoken language, images are not linear, but more synchronous, like a woven fabric (Paivio 1991), and using them would thus seem to avoid some of the snags to which language alone is prone. The visual language (Rudwick 1976) of surgery is one which has a long, complex history (much longer in fact than that of Rudwick's own context of geology), and comprises various types of anatomical textbooks and atlases, specialist journal articles, surgical manuals, and for orthopaedic surgeons, radiological atlases also. In chapter 3, I briefly outlined the history of anatomical illustration. This is important, because it is a history that is still being written, with the emergence of new techniques and technologies for visualising the body. It is important also because it appears that surgeons 'construct' the actual body in much the same way as anatomical pictures of it are constructed. They reduce it to the immediate area of concern, for example, and then 'enhance' this area by the various means available to them. This enhancement may include the use of language (in that they sometimes 'talk' their way through the identification of the various bodily structures that they encounter), and pictures.

Hirschauer (1991) described this process as one in which the *actual* body becomes merged with the *anatomical* body encoded in these pictures. This is a protracted process, which involves skills that take a long time to acquire. We encountered this process at the outset, in the ways in which veterinary student Richard and his colleagues revised for their anatomy examinations not only with their textbooks, but with the living bodies of their pet animals also. We observed it also in the later stages, when experienced surgeons would pore over textbooks across the prone bodies of anaesthetised animals. As well as involving bodies, pictures and texts however, this process also entails social interaction. Knowledge about surgery is largely constructed and transferred as a result of social processes. Initially, anatomy is learned by rote, from lecture notes and textbooks. Structures encoded in these notes and books may then be identified in relation to live animals at home or in the operating theatre, or to dead animals in dissection classes. Later, these processes continue through actual and vicarious participation in operations. However, I run ahead of myself.

I would like to call attention here to the roles of what I have called the 'enhancement and reduction procedures'[1] to which patients' bodies are subjected prior to surgery, and of the 'further enhancement procedures' which may be applied during its actual course. The former procedures are ostensibly for the purpose of maintaining sterility, thus avoiding the possibility of post-operative infection. However, I have presented evidence that indicates that they are also used as bodymapping strategies. The patient's gross anatomy is effectively 'reduced' to the salient part for the particular operation in question; thus for spay operations, it is 'reduced' to the abdomen. This is done via the shaving of the operative site, draping and so on. At the same time it is 'enhanced', initially by means of positioning techniques and aids. All of these procedures function to help visually 'reduce' the gross body, 'enhancing' its salient areas, and thereby rendering it more like the content of 2D anatomical pictures. The actual body thus becomes 'merged' with the anatomical body initially acquired from such pictures. I have summarised these procedures in tabular form in Fig13 below.

Primary enhancement procedures	Reduction procedures	Direct further enhancement procedures	Indirect further enhancement procedures
Use of positioning aids; support cradle, hind limbs tied to operating table to allow maximum access to site. (Op. 1 section 8.4, Op. 2 section 8.6, Op. 3 section 8.7)	Shaving of site, draping (Op. 1 section 8.4) Use of 'spay cloth' with small slit cut in centre by RH, in case of very small incision (Ops. 2, 3, sections 8.6, 8.7)	James' use of swabs as a 'visual aid' to cover 'unwanted' internal organs in Op. 1 (section 8.4)	RH's use of bodymapping talk when locating abnormal ovary (Op. 3, section 8.7)
	Swabbing of site with coloured antiseptic (all except for Op. 5 (section 9.2)	James' extensive use of instrumentation in Op. 1 (section 8.4), use of forceps, retractors etc to separate organs and hold wound open.	Use of pictures (in surgical textbooks and atlases, plus radiographs) by operating surgeons (Op. 4, section 9.1; Op. 5, section 9.2; Op.8, section 9.3.3)
WW's 'trying out' of several positions before deciding on the one that offered maximum access to the medial aspect of the lower forelimb (Op. 4, section 9.1)	Careful draping by surgeon, Ops. 4, 6, 7, 8, (sections 9.1, 9.3.1, 9.3.2, 9.3.3), using rectangles of fabric and towel clips to effectively 'cut off' the affected limb from the rest of the body.	Importance of staunching blood flow to maximise visibility, even small 'oozes' that can be of no danger to the patient. (All ops)	Use of pictures (in surgical textbooks and atlases, plus radiographs) by surgeons peripheral to procedures - participating in 'virtual surgery' (Op. 4, section 9.1; Op. 5 section 9.2)
	NB: NO draping of hard palate patient (Op. 5, section 9.2)		Social interaction -collaborative operating (Op 4, section 9.1, Op 5, section 9.2)
		Change of position of 'hard palate' cat, from lateral (as shown in book) to dorsal recumbency (Op.5, section 9.2)	Verbal bodymapping by IM when lots of interruptions (Op. 6, section 9.3.1)
Alison's positioning of 'hard palate' cat to match the position of the one pictured in the textbook (Op. 5, section 9.2)	BMc's covering of the foot of his cruciate patient with a drawstring bag (Op. 8, section 9.3.3)		

Fig 13: Table to show primary enhancement, reduction and further enhancement procedures, with examples.

I argue for this purpose of pre-operative procedures on the basis of their observed differential usage by surgeons who had accrued differing amounts of experience in respect of the operation in question. For routine operations, experienced surgeons took less trouble over these procedures than did novices. Since risk of infection (for the same operation, carried out in the same conditions upon the same species of animals) is hardly likely to vary to any great extent, it seems therefore that these procedures play quite another role apart from that of infection prevention. They are also used as visual aids to bodymapping. As is customary in talking about perceptual information, I have emphasised the visual. However, visual data is invariably complemented by that from other sensory modalities. Surgeons referred for example to the 'feel' of certain bodily tissues, and also on occasion to specific 'sounds' that they listen for. My use of the term 'visual aids' (which was 'borrowed' from a respondent) must therefore be seen in the light of this.

Once the surgery is underway, what I have called 'further enhancement' procedures may also be applied. These may be visual, or verbal in nature. 'Visual' ones can in addition be direct (that is, applied directly to the patient's body, as with James' use of the swab in operation 1 to conceal 'unwanted' organs), or indirect, involving pictures, which may be anatomical pictures or images derived from visualisation technologies such as radiography. Verbal bodymapping also, may be resorted to. In this instance, the surgeon may actually 'talk his or her way' through identifying the various bodily organs and tissues that s/he encounters. On the whole, further enhancement procedures are similar to the enhancement and reduction procedures described formerly, in that they also tend to be used more frequently and more comprehensively by the inexperienced. However, it was observed that experienced surgeons also engaged in these behaviours in situations of uncertainty. Like the outsides of bodies, their insides also frequently differ, and this can lead to uncertainty where a surgeon encounters a variant that s/he has not come across before. S/he will often in such instances engage in verbal bodymapping.

Further enhancement procedures are interesting also in that they may be 'used' by surgeons who are peripheral to the operation in question, as well as those who are actually participating in its performance. I have presented evidence which indicates that surgeons become able over time to map the body through their experiences of participating in actual and virtual operations. On several occasions where an unfamiliar operation was being performed, or one acknowledged for some or other reason to be 'harder' than average, groups of surgeons congregated around the actual surgery, and (particularly) visual representations of it, verbally rehearsing alternative strategies for carrying it out. Initial anatomical knowledge learned by rote from pictures and textbook accounts is thus applied via participation and collaboration in *virtual* and *actual* operations. The form of these 'virtual' operations may be simple initially, for example, the comparison of anatomical textbook pictures with the anatomy of actual animals, as reported by student surgeon Richard could be seen in this light. Later, complex social interactions around visual representations at the scene of actual operations may take place. Veterinary surgical knowledge is thus constructed at least in part by social means.

10.4.3 In what ways do surgeons mediate uncertainty in relation to the body?

Some aspects of this question have already been answered. Surgeons use the further enhancement processes discussed earlier, in situations of uncertainty. However, how exactly can we define a 'situation of uncertainty'? Experienced surgeons spoke of ways in which their experience had been built up over time in relation to mental 'libraries of cases' which they had accrued. Uncertainty therefore, it would seem, results when a surgeon encounters a case which for some reason is unlike any other case which s/he has come across before. Most of these problem situations can be related to variations that occur in anatomy, or to difficulties in relating actual bodies to textbook representations of them. This latter point was raised in the previous section, but it might prove useful to reflect a little more upon surgeons' strategies for dealing with anatomical variations. Further enhancement procedures can be used as *physical* aids as we have seen. Since we have already looked at visual (or more properly, perhaps, perceptual) variants of these at some length, it might prove instructive here to reflect a little more upon verbal strategies. We will also consider the relevance of evidence from Schunn and Klahr (2000) who showed how, when confronted with a confusing situations, participants in a series of experiments relating to solving computer programming problems temporarily switched their attention to less confusing aspects. Finally, I will argue for the usefulness of the abductive mode of inference in accounting for surgeons' mediation of uncertain situations.

Fieldwork data has provided us with evidence of verbal bodymapping during operations, and this is complemented also by evidence from the literature (Hirschauer 1991; Pinch *et al* 1996). Off-task and on-task talk during operations is a useful evidential form because of the insights that it can provide into skill. Skill thus becomes visible and invisible to the observer via on-task and off-task talk On-task talk, that is, talk about the procedure itself, or about the anatomy encountered, renders surgeons' skills visible. This skill does not disappear however on those occasions when off-task talk (which is talk about topics other than the procedure in hand, often casual chat) takes place. The skill is still there, and still being exercised. It is however rendered tacit. Perhaps unsurprisingly, experienced surgeons tended to engage in off-task talk more than novices, who needed to concentrate far more upon the task in hand. Recordings of talk by surgeons during operations revealed that a significant proportion of on-task talk is related to bodymapping. Other topics ranged from surgical techniques to more general discussion of the types of injuries encountered, and surmising possible causes for these.

Bodymapping talk is particularly interesting, in that it does not necessarily appear to be directed at anyone else present. Surgeons were observed to *talk* their way through the identification of organs and tissues, in unfamiliar or uncertain situations. Interviews with veterinary nurses too, confirmed that 'their' surgeons customarily engaged in this behaviour when uncertainty arose. At certain *stages* of operations, such as the initial incision (to make sure that it was made in the optimum place), and in the location of tissues that were particularly salient to the procedure in question, particular concentration was needed. Thus bodymapping talk was more likely to occur, and off-task talk to be absent, at these stages. This accords with verbal evidence from surgeons JH and BMc who spoke of 'crucial stages' during operations when it is necessary for a surgeon to concentrate all of his or her resources upon the task in hand.

Although fairly speculative in the case of surgery (since evidence from fieldwork data is thin in this respect), I would like to mention metaphor before concluding this short discussion of language-related strategies for mediating uncertainty. In chapter 5, we explored ways in which this term can be applied, as a 'figure of speech' for example, or more fundamentally, as a tool for thinking whereby aspects of something are thought about as some other thing. Thus abstract or unfamiliar concepts can be thought about in terms of more concrete or familiar concepts. I have already discussed my disquiet with this 'abstract' and 'concrete' terminology. However, I resort to their use due to the lack of any alternative; (in a 'metaphorical' sense perhaps?) Metaphor is thus seen to be a potentially more useful linguistic device for communicating complexity, or ambiguity than others that we have encountered, such as narrative or propositional language. Sculptor respondents referred several times to the difficulties involved in trying to express some issues related to their work in words. Metaphor was sometimes able to mediate this difficulty. The metaphor of evolution for instance, was employed to explain how their work developed and progressed over time. This usefulness of metaphor in communicating topics that are difficult to put into words, may be compared to the uses that we make of pictures for similar purposes.

Moving on from *communicating* uncertainty, to the more mechanical topic of *acting* in the face of it, the work of David Klahr and his associates (2000) is useful in that it highlights the similarities that exist between everyday activities and scientific discovery. This work consists of a series of studies in which participants were asked to conduct experiments by using computer 'microworlds' in which they controlled the actions of animated devices. Their aim was to discover the effects of specific unknown functions. In one particular study, Schunn and Klahr (2000 pp161-199) presented a complex discovery microworld called 'Milk Truck' to a group of 22 undergraduate students, in an attempt to reveal heuristics and strategies that people use to deal with task complexity. 50% of these participants went on to successfully complete the task, and the other 50% either gave up or reached an incorrect solution. Schunn and Klahr characterised their activities in terms of 'searches' of two 'spaces', a 'hypothesis space' and an 'experiment space'. They showed how, in searches of the experiment space, when confronted with a confusing aspect of a problem, several successful participants used what they termed the PUSH (put up on stack) heuristic, temporarily switching to another aspect that was less confusing. This strategy was apparently useful in three ways. Firstly, by allowing participants to work on a different aspect of the problem, PUSH enabled new ideas to be activated in the hypothesis space search, ie, it allowed the formation of new hypotheses.

Secondly, the investigation of a different problem can suggest new operations that can be applied to the old situation thereby improving the experiment space search. Thirdly, in inducing a complex concept involving interactions (such as those underlying the mystery command), '*discoveries about one part of the concept aids discoveries about another part of the concept*' (ibid p.174).

PUSH aids then, in the production of novel solutions (or solutions to novel problems perhaps), and a version of this was observed in operation 3, where RH was confronted with an abnormal variant of canine reproductive anatomy that he had not before encountered. This strategy would therefore also seem to be one that is of use when thinking about the ways in which surgeons deal with uncertainty or ambiguity. It would also seem to suggest that there are many similarities between surgical practice and other skills.

Thus we link the *physical* dimensions of mediating uncertainty, taken to be those aspects that are directly available to the observer for example through visual or verbal means, with the *cognitive* ones, about which we can only surmise, and make suppositions based upon the perceptual evidence available to us. I would argue that many surgical problems (particularly those that relate to anatomical ambiguities) are not amenable to solution by logical means alone, since insufficient evidence is available to effectively apply logic. This discounts then, the sole use of deductive or inductive modes of inference as sufficient explanation. I argue therefore for the abductive model of inference which allows for creative 'leaps' to be made, from what is known (for example, from one's previous experience, or information that can be found in a textbook or obtained from a colleague), to what is not yet known. As Gooding (1990, ch.1) pointed out however, practical procedures such as those that I have been investigating, are often later reconstructed so that they *appear* logical in retrospect.

Abduction can be characterised as a scheme which incorporates both intuitive and logical moves, and verbal, symbolic or image based representation, and can thus 'fill the gap' of knowledge that can exist between the present case and a slightly different one experienced previously, explaining the 'working hypotheses' formed by my respondents to account for ambiguous perceptual data during surgical operations, and for alterations that were seemingly automatically made to previously-stated plans. Although the unfamiliar anatomical or physiological variant is not the same as any previously encountered, some *aspects* of it will be the same. Practitioners therefore identify these familiar aspects, and abduce novel solutions from this basis. As Josephson and Josephson (1996) pointed out, abductions are fallible and doubt cannot be completely eliminated. However, they enable action to be taken 'on the run' in situations of uncertainty which require immediate attention.

This strategy of course requires that the practitioner in question *has* some degree of personal experience in relation to the problem in question. As we have already seen however, such experience can be *virtual* (ie acquired by vicarious participation in surgery that is being performed by others), as well as *actual*. It can be argued that all surgeons, even students like Richard, will thus have some small amount of experience upon which to base solutions, and even he would have the ability to make small abductions on the basis of this. However, the scope of these would be very limited, since presumably, insufficient aspects of the situation in hand would be recognisable to him to enable him to solve any but the simplest problems without help. Also, vicarious participation in operations alone (though important), does not provide the opportunity for the acquisition of *embodied* experience (which may relate for example to the feel of the tissues, or the manipulation of instruments), in the same way as *actual* participation. Thus the importance of *both* types of experiences needs to be taken into consideration.

10.4 4 In what ways *do* all *of* these things change in nature as surgeons gain in experience?

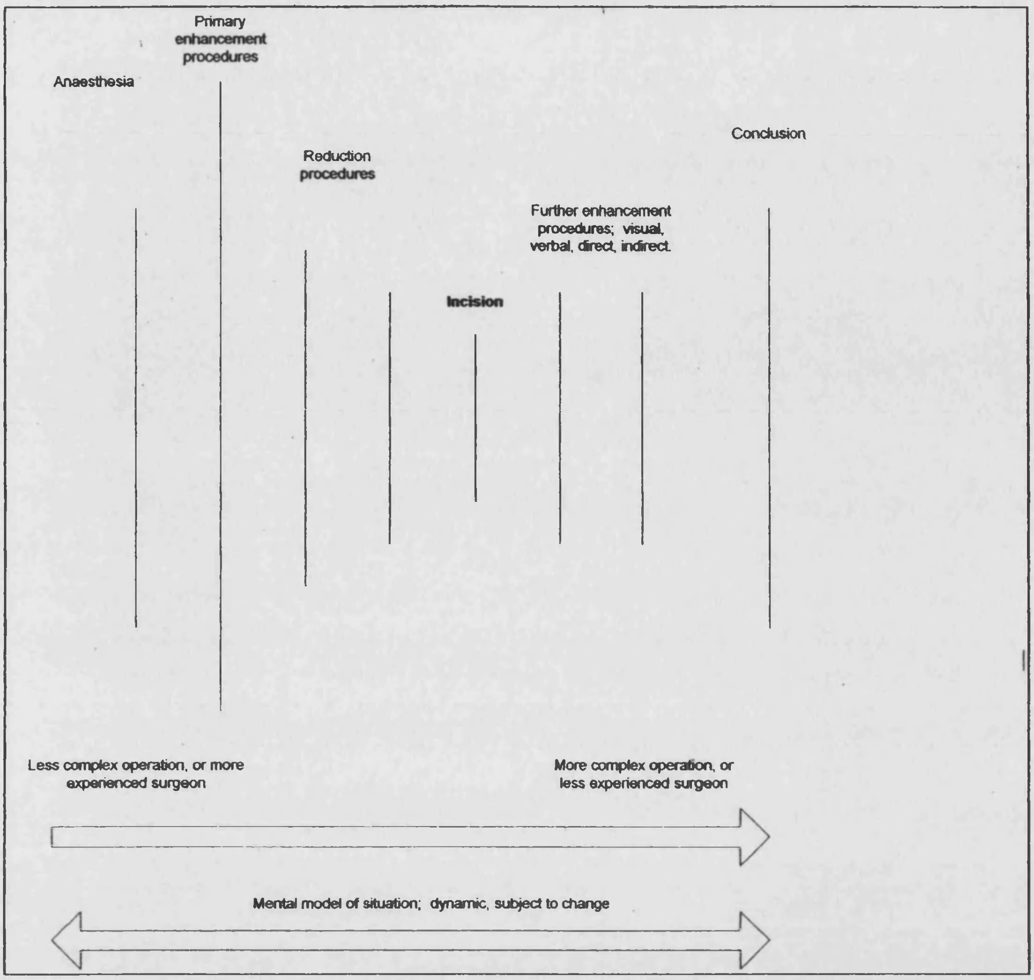
Clear differences exist in the performance of surgeons with less experience in comparison to those with greater experience. For example, we have seen that primary enhancement and reduction processes may be less stringently applied by experienced surgeons, and further enhancement procedures may also be used less, or differently. Self-preparation of the surgeon may also be performed less stringently, although beginners and acknowledged experts may 'use' this for different purposes. These preparations can also be seen (in addition to the usual explanation given, which is that they are indispensable for the purposes of infection prevention), in relation to surgeons' presentation of self (Goffman 1961). The scrupulous preparations that were undertaken by newly qualified surgeon James and by consultant orthopaedic surgeon IM for example, were interesting in that these two practitioners would seem to be almost at either end of the spectrum of experience, and the bulk of surgeons who were situated experientially in the middle of this spectrum took considerably less trouble over these preparations. It could be surmised that, while James might have seen these procedures as a defining characteristic of the form-of-life of surgeons into which he had recently been admitted, IM may in contrast have used them to detach himself in some respects from this 'ordinary' veterinary form-of-life. Use of humour too, can play an important part in presentation of self. IM referred to jokes that exist in 'veterinary orthopaedic circles'; circles which are by definition separate from 'ordinary' veterinary circles.

Inexperience renders a practitioner liable to need to concentrate more of his / her resources on mapping the body, and this may detract from their ability to notice and / or prioritise other (important) things. This was observed in relation to James, who had to be reminded about the vulnerability of the spleen to damage during certain stages of the spay operation. In addition, (perhaps understandably), experts were observed to take less time to perform a given procedure, and tended to use fewer instruments and smaller incisions. Somewhat more surprisingly however, not only did they seem to possess an ability to cut corners, and simplify complex procedures to some extent, but they were also observed to choose less complex (and hence more straightforward) methods in the first place, where these were available, and in some cases to invent new ones of their own if not. This was shown for example in relation to cruciate repair operations carried out by IM as compared to that performed by BMc.

Dreyfus and Dreyfus (1986) and Benner (1984) stressed the importance to novices of context-free rules which can be applied in every situation. They stated that, as actual experience is gained, it is necessary that these rules are put aside to allow progression to higher skill levels. These algorithmic rules are replaced by heuristics, or 'rules of thumb'. This could be turned on its head thus: what if it is not the rules *themselves* that change (for example, in their content, or the way in which they are worded or otherwise encoded), but rather people's use of them? Measurements for instance, may be more or less accurate, or sampled by means of more or less precise techniques or apparatus; but they are still measurements. What is most important, seems to be the circumstances in which they are used, rather then the actual measurements themselves. Whether gauging the circumference of an object with the aid of a piece of string, or measuring minute fractions in the blood by means of complex assay techniques, measurements can be used either in the sense of 'rules' or 'rules of thumb'. Experts tend towards the latter use, while novices cannot conceive of any other than the former. However, when the same experts are forced for some reason to use them algorithmically, they experience the same sort of uncertainties as novices. This indicates that novices *do not* put aside 'the rules' as they become more experienced. The rules are still there, essentially the same. They merely change the way in which they use them. I have discussed algorithmic and heuristic rules in terms of categories, and in terms of measurements. This contrasts somewhat with accounts of 'the rules' as sets of propositions or instructions (Benner 1984; Collins 1986; Dreyfus and Dreyfus 1986). I see no reason however why they cannot be encoded in other formats. Artist respondents reported difficulty in using pictures either as 'blueprints' or plans for their work (ie, as a draughtsman would make them), or as models to copy directly, and observations of surgeons indicated similar difficulties. Pictures too, it would seem, can be used either algorithmically or heuristically.

10.5 Graphic renderings?

Alongside the necessity to address the research question itself, I have set myself another, altogether different task; to render my exposition *graphically*. That is, in diagrammatic form, alongside text, in the tradition of the 'visual languages' that have emerged for burgeoning scientific disciplines, including geology, and anatomy. I thus employ some of the techniques of anatomy for myself. I have provided several diagrams which are intended to help focus on changing aspects of some of the processes that I have described, providing further explication beyond that of the textual account itself. It remains for me to 'complete the picture' by providing one further diagram, shown in Fig. 14 below.



<u>Fig. 14 Completing the picture: a generalised model of surgical operations.</u>

In this diagram, I have tried to show how primary enhancement, reduction and further enhancement procedures may be differentially used by more and less experienced surgeons, or in more or less complex surgery. It is important to note that by 'experienced', I mean possessing experience *in relation to that specific surgical procedure.* Surgery, and for that matter sculpture also, have much to commend them as contexts in which to investigate further aspects of skill. They have provided me not only with opportunities to 'research' the activities of proponents of these disciplines, but also with opportunities to reflect upon the nature of research, and research methods themselves. I would personally like to carry out further research with student and newly qualified surgeons, to try to discover in more detail the ways in which (and the point at which) they change in their approach to 'the rules'. Also, I have speculated that 'rules' can take other forms than sets of instructions or propositions, as categories or other means of classification, or measurements for example, or possibly even of certain kinds of pictures. This too, is a topic which would be very interesting to take further.

To conclude, thinking back to my very first sentence for a moment, I have attempted to provide insights into what is entailed in 'Knowing, seeing and how we come to know and see'. The quote which heads this chapter represents one way of thinking about surgeons' skills. Hirschauer has broken down the complex bundle of skills necessary for performing a surgical operation into smaller (and hence less complex) units. He has then related or compared these to (parts of) other occupational skills. As the quote indicates, surgery thus has many aspects in common with other skills. This type of investigation could therefore in theory have been carried out in the context of almost any other skilled practice. The pilot study described in chapter 7 which features evidence from sculptors, provides contrast which serves to demonstrate that many of these things are more widely applicable beyond any one practice, and hence that similarities exist between practices that are often thought about as belonging to entirely different spheres. A key link is that of *skill.* Skill, and its development thus encapsulate, and demonstrate similarities across different disciplines and different practices.

Finally, my experiment with 'graphic renderings', though to some extent unsatisfactory (since it did *not* after all enable me to escape the limitations of the narrative form), has however, by combining verbal / narrative and graphical / non-linear modes of representation, enabled me to convey something more than either alone could have done. Any mode of representation offers opportunities, as well as limitations, and it is therefore an experiment that is worth repeating, perhaps by trying out different diagrammatic forms for different activities. 'Research methods', rather than being inscribed in tablets of stone, as tends to come across in the teaching of them (and I have been equally as guilty as anyone in this respect, in my own teaching), should, I feel, be thought about in a more 'experimental' sense. Researchers should not be afraid to challenge accepted methodologies, to adapt them, and to use them in unorthodox ways. What they *must* do of course, is to be quite explicit about this, if the integrity of research to be maintained. I hope that if nothing else, this work reopens debates about methodologies. Researchers must be reflective about the methods they use, rather than adopt them merely through habit or conventional usage. If by challenging to some extent methodological conventions (which is probably a somewhat unwise thing to do in a doctoral thesis), I have encouraged this reflectiveness, then I feel that I have in some small way succeeded in contributing to current and future debates, and that the hard work has been worthwhile.

I have come to the end of this present work, yet in many ways the real work is only just beginning. Northrop Frye (1947) an eminent practitioner in a discipline quite apart from any of those in which I have dabbled here, described how a doctoral thesis is useful for encouraging intensive reading (or in this case perhaps, extensive reading), but of relatively little use for gaining 'literary perspective', which takes years to develop and cannot be hurried. I consider this a fitting way in which to think about my efforts here. This is but a small contribution to the study of the vast topic of human knowledge and skills (or for that matter, that of researching them also). Much is left to do, and to discover, by whatever methods are available to us. On this note, I finish.

NOTES

1 I have adopted David Gooding's terminology to describe these processes. In doing so, I am making an analogy only. As he suggested I point out, his term denoted something very specific; the adding and removing of dimensions of a *representation*. I have used it in a more 'literal' or 'physical' sense, in respect of procedures that were applied to actual operations.

APPENDIX: EXAMPLE OF FORM USED TO RECORD CONVERSATION ETC IN THE FIELD

OBSERVATIONAL RECORDING CHART

Initials/ Procedure Date	Pre-operative procedures	Off-task talk	Decision difficulties	Concurrent activities	Talking through procedures	Use of senses other than sight

REFERENCES

Abbott, E.A. (1884). *Flatland: A Romance of Many Dimensions.* London.

Aldrich, S. (1997). *Making sense of everyday pain.* Unpublished MSc thesis: University of Bath.

Alpers, S. (1983). *The Art of Describing.* Chicago: University of Chicago Press.

Amann, K. and Knorr-Cetina, K (1988). 'The fixation of visual evidence'. *Human Studies* 11, 133-169.

Anderson, J.R. (1978). Arguments concerning representations for mental imagery. *Psychological Review* 85, 249-277.

Anderson, J.R. (1983). *The Architecture of Cognition.* Cambridge, MA: Harvard University Press.

Anderson, J.R. (1987). 'Skill Acquisition: Compilation of weak-method problem solutions.' *Psychological Review* 94, 192-210.

Anderson, J.R. (1993). *Rules of the Mind.* Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Anderson, J.R. and Bower, G.H. (1973). *Human Associative Memory.* N.Y: V.H. Winston.

Arnheim, R. (1971). *Visual Thinking.* Berkeley and Los Angeles: University of California Press.

Asad, T. (Ed.) (1973). *Anthropology and the Colonial Encounter.* London: Ithaca Press.

Atkinson, P. & Heath, C. (1981). *Medical Work: Realities and Routines.* Farnborough: Gower.

Atkinson, P. (1990). *The Ethnographic Imagination: textual constructions of reality.* London: Routledge.

Atkinson, P. (1995). *Medical Talk and Medical Work: The Liturgy of the Clinic.* London: Sage.

Azar, B. (1998). 'From Surgery to Robotics, touch is the key'. *APA Monitor* Vol 29, no.6, June 1998. Accessed via http://www.apa.org/monitor/jun98/object.html

Baddeley, A.D. and Hitch, G.J. (1974). 'Working Memory'. In G.H. Bower (Ed.) *The Psychology of Learning and Motivation* (Vol 8), 47-89. London: Academic Press.

Baddeley, A.D. (1990). *Human Memory: Theory and practice.* Hove, UK: Lawrence Erlbaum Associates Ltd.

Baker, M. (1998). 'The 3D Model in Eighteenth Century Design Procedures: The representation and viewing of process'. Paper given at the Wellcome Symposium for the History of Medicine (with the Science Museum) *Models in the sciences, technology and medicine: displaying the third dimension.* Wellcome Institute and Science Museum, London, 13-14 November 1998.

Barnes, B., Bloor, D. And Henry, J; (1996). *Scientific Knowledge: A Sociological Analysis.* London: Athlone Press.

Bartlett, F.C. (1932). *Remembering: a study in experimental and social psychology.* Cambridge: Cambridge University Press.

Bartlett, F.C. (1958). *Thinking.* London: Allen and Unwin.

Beaulieu, A (2000). *The Space inside the Skull: Digital Representations, Brain Mapping and Cognitive Neuroscience in the Decade of the Brain.* University of Amsterdam: PhD thesis.

Benner, P. (1984). *From Novice to Expert: Excellence and Power in Clinical Nursing Practice.* Menlo Park, CA: Addison-Wesley.

Bennett, A. and Royle, N. (1999). *Introduction to Literature Criticism and Theory* (2nd Ed.). London: Prentice Hall.

de Bernieres, L. (1994). *Captain Corelli's Mandolin.* London: Minerva.

Berreman, G. (1966). 'Anemic and emetic analyses in social anthropology.' *American Anthropologist* 68 (2) 1: 346-54.

Blois, M. (1980). Clinical Judgement and Computers. *New England Journal of Medicine* Vol 303 (no.4): 192-197.

Bloxham, P. (1994). 'Diagnostic Tests'. In Lane, D.R. and Cooper, B. (Eds) *Veterinary Nursing* 231-237. Oxford: Elsevier Science.

Borrell, M. (1986). 'Extending the Senses: The Graphical Method'. *Medical Heritage* 2: 114-121.

Bower, G.H., Clark, M.C., Lesgold, A.M. and Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning and Verbal Behaviour* 8: 323-43.

Bowker, G.C. and Star, S.L. (1999). *Sorting Things Out: classification and its consequences.* Cambridge, MA, London, UK: MIT Press.

Boyd, J.S. (1991). *Clinical Anatomy of the Dog and Cat.* London: Wolfe Publishing.

Brecher, R and Brecher, E. (1969). *The Rays: A History of Radiology in the United States and Canada.* Baltimore: Williams and Williams.

Brown, R. (1956). Language and categories. In Bruner, J.S., Goodnow, J.J. and Austin, G.A. *A Study of Thinking* 247-312. New York: Wiley.

Brown, J.S. and de Kleer, J. (1981). Mental models of physical mechanisms and their acquisition. In Anderson, J.R. (Ed). *Cognitive Skills and their Acquisition.* Hillsdale, NJ: Erlbaum.

Bryan, W.L. and Harter, N. (1899). 'Studies on the telegraphic language: The acquisition of a hierarchy of habits'. *Psychological Review* 6, 345-375.

Camerini, J. (1993). Evolution, Biogeography, and Maps: an Early History of Wallace's Line. *Isis* **84**: 700-727.

Carlson-Radvansky, L.A. and Irwin, D.E. (1994). 'Reference Frame Activation during Spatial Term Assignment' *Journal of Memory and Language* 33: 646-671.

Carpenter, P.A. and Just, M.A. (1975). Sentence Comprehension: a psycholinguistic processing model of verification. *Psychological Review* **82**: 45-73.

Cassell, J. (1987). 'On control, Certitude and the 'Paranoia' of Surgeons.' *Culture, Medicine and Psychiatry* Vol 11, 229-49.

Cazort, M., Kornell, M, and Roberts, K.B. (1996). *The Ingenious Machine of Nature: Four Centuries of Art and Anatomy.* Ottawa: The National Gallery of Canada.

de Chadarevian, S. (1993). 'Graphical methods and discipline: Self-recording instruments in nineteenth-century physiology.' *Studies in the History and Philosophy of Science* June 1993, 267-291.

Charness, N. (1979). Components of Skill in Bridge. *Canadian Journal of Psychology / Review Canadian Psychology.* 33: 1-16.

Chase, W.G. (1983). Spatial representations of taxi drivers. In Rogers, D.R. and Sloboda, J.H. (eds). *Acquisition of Symbolic Skills* 391-405. NY: Plenum.

Chase W.G. and Simon, H.A. (1973). Perception in Chess. *Cognitive Psychology* 4: 55-81.

Chi, M.T.H., Feltovich, P.J. and Glaser, R. (1981). Categorisation and Representation of Physics Problems by Experts and Novices. *Cognitive Science* 5: 121-152.

Chiesi, H.L., Spilich, G.J. and Voss, J.F. (1979). Acquisition of Domain-Related Information in Relation to High and Low Domain Knowledge. *Journal of Verbal Learning and Verbal Behaviour* 18: 257-273.

Clark, H.H. (1974). Some aspects of the conceptual basis for first language acquisition. In Schiefelbusch, R.L. and Lloyd, L.L. (eds) *Language Perspectives: acquisition, retardation, and intervention.* Baltimore: University Park Press.

Clark, A. (1997). *Being There: Putting Brain, Body and World Together Again.* Cambridge, MA: MIT Press.

Clement, J. (1988). Observed methods for generating analogies in scientific problem solving. *Cognitive Science* **12**: 563-86.

Cole, M., Gay, J., Glick, J. And Sharp, D. (1971). *The Cultural Context of Learning and Thinking.* New York: Basic Books.

Cole M. and Scribner, S; (1974). *Culture and Thought: a psychological introduction.* New York: Wiley.

Cole, M., Scribner, S., John-Steiner, V and Souderman, E. (1978). *Mind in Society.* Cambridge, MA: Harvard Unicversity Press.

Cole, M., Engstrom, Y. and Vasquez, O. (eds). (1997). *Mind, Culture and Activity.* Cambridge: Cambridge University Press.

Collins, H.M; (1974). 'The TEA Set: Tacit Knowledge and Scientific Networks'. *Science Studies,*4: 165-86.

Collins, H.M. and Harrison, R; (1975). 'Building a TEA Laser: The Caprices of Communication'. *Social Studies of Science,* 5: 441-5

Collins, H.M (1985). *Changing Order: Replication and Induction in Scientific Practice.* London: Sage.

Collins, H.M (1990). *Artificial Experts: Social Knowledge and Intelligent Machines.* London: MIT Press.

Collins, H.M (1992). *Changing Order: Replication and Induction in Scientific Practice.* Chicago: University of Chicago Press Edition.

Collins, A. and Gentner, D. (1986). How people construct mental models. In Holland, D. and Quinn, N. (eds). *Cultural models in language and thought,* 243-266. Cambridge: Cambridge University Press.

Cooke, N.J. (1992). Modeling Human Expertise in Expert Systems. In Hoffman, R., *Psychology of Expertise.* Berlin: Springer Verlag.

Craik, K.J.W. (1943). *The Nature of Explanation.* Cambridge: Cambridge University Press.

Crary, J. (1990). *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century.* Cambridge, MA; London, UK: MIT Press.

Curt, B. (1994). *Textuality and Tectonics: Troubling Social and Psychological Science.* Buckingham and Philadelphia: Open University Press.

Darzi, A. (2000). 'Setting the Scene: barber surgeons'. Paper given at *Visualisation in Surgery* symposium at Imperial College. Part of the BA Festival of Science. Saturday 9 September 2000.

Dawkins, R. (1989). *The Selfish Gene.* Oxford, New York: Oxford University Press.

de Jong, G. (1988). An introduction to explanation-based learning. In H.E. Shrobe (ed) *Exploring Artificial Intelligence: Survey Talks from the National Conferences on Artificial Intelligence* (pp. 45-81). San Mateo, CA: Morgan Kaufmann.

de Kleer, J. and Brown, J.S. (1983). Assumptions and ambiguities in mechanistic mental models. In Gentner, D. And Stevens, A. (Eds). *Mental Models.* Hillsdale, NJ: Erlbaum.

Dennis, M.A. (1989). Graphic Understanding: Instruments and Interpretation in Robert Hooke's *Micrographia. Science in Context* Vol 3 (2) 306-364.

Denzin, N.K. (1970). *The Research Act in Sociology,* London: Butterworths.

Dreyfus, H.L. (1979). *What Computers Can't Do.* NY: Harper and Row.

Dreyfus, H.L. (1992). *What Computers Still Can't Do: A critique of artificial reason.* Cambridge, MA, London UK: MIT Press.

Dreyfus, H.L. and Dreyfus, S.E. (1986). *Mind over Machine.* Cambridge, MA, London UK: MIT Press.

Eco, U. and Seboek, T.A. (1983) *The Sign of Three: Dupin, Holmes, Peirce.* Bloomington and Indianapolis: Indiana University Press.

Ehrlich, K. (1996). Applied Mental Models in Human-Computer Interaction. In Oakhill J. And Garnham, A. (Eds) *Mental Models in Cognitive Science: essays in honour of Phil Johnson-Laird* 223-245. Hove: Psychology Press.

Eraut, M. (1994). *Developing Professional Knowledge and Competence.* London: Falmer.

Erickson, J.R. (1973). A set analysis theory of behaviour in formal syllogistic reasoning tasks. Paper presented to the Loyola Symposium on Cognition. Chicago, May 1973.

Etzioni, A. (Ed). (1969). *The Semi-Professions and Their Organisation.* NY: Free Press.

Farah, M.J. (1988). Is visual imagery really visual? Overlooked evidence for a shared representational medium for mental images and percepts. *Psychological Review* 95, 307-317.

Farah, M.J., Soso, M.J. and Dashieff, R.M. (1992). Visual angle of the mind's eye before and after unilateral occiputal lobectomy. *Journal of Experimental Psychology: Human Perception and Performance* 18, 241-246.

Fielding, N. (1993). 'Ethnography'. In Gilbert, N. (Ed). *Researching Social Life* 154-172. London: Sage.

Fitts, P.M. and Posner, M.I. (1967) *Human Performance.* Belmont, CA: Brooks-Cole.

Fodor, J. (1981). *Representations.* Brighton: Harvester.

Fodor J. (1983) *The Modularity of Mind.* Cambridge, MA: MIT Press.

Forester, C.S. (1964). *The Hornblower Companion.* Toronto: Little, Brown and Co.

Friedhoff, R.M. and Benzon, M. (1991) *The Second Computer Revolution; Visualization.* Los Angeles: W.H. Freeman.

Frye, N. (1947). *Fearful Symmetry: A Study of William Blake.* Princeton: Princeton University Press.

Garfinkel, H. (1967). *Studies in Ethnomethodology.* Englewood Cliffs, NJ: Prentice-Hall.

Garnham, A. and Oakhill, J. (1994). *Thinking and Reasoning.* Oxford: Blackwell.

Geertz, C. (1973). *The Interpretation of Cultures; Selected Essays.* New York: Basic Books.

Gellately, A; (ed) (1986). *The Skilful Mind.* Milton Keynes: Open University Press.

Gentner, D. (1983). Structure-mapping: a theoretical framework for analogy. *Cognitive Science* 7: 155-170.

Gentner, D. and Stevens, A. (1983) (eds). *Mental Models.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Gladwin, T. (1964). *East is a big bird.* Cambridge: Harvard University Press.

Goffman, E. (1961). *Encounters: Two Studies in the Sociology of Interaction.* NY: Bobbs-Merrill.

Goldsmith, E. (1984). *Research into Illustration: an approach and a review.* Cambridge: Cambridge University Press.

Gombrich, E. (1959). *Art and Illusion.* Oxford: Phaidon Press.

Goodfield, J. (1991). *An Imagined World.* Ann Arbor, Mich.: University of Michigan Press.

Gooding, D. (1990). *Experiment and the Making of Meaning.* Dordrecht and Boston: Kluwer Academic.

Gooding, D. (1996a). 'Creative Rationality: Towards an Abductive Model of Scientific Change'. *Philosophica* 58 (2) pp. 73-102.

Gooding, D. (1996b). 'Scientific Discovery as Creative Exploration: Faraday's Experiments'. *Creativity Research Journal* Vol 9, Nos. 2-3: 198-205.

Goodwin, B. (1994). *How the Leopard Changed its Spots.* London: Weidenfeld and Nicholson.

Gordon, S.E. (1992). Implications of cognitive theory for knowledge acquisition. In Hoffman, R. *Psychology of Expertise.* Berlin: Springer Verlag.

Guide Dogs for the Blind Association (1996). *Neutering of the Bitch: Spaying.* One of a series of videos showing the work of the GDBA's breeding programme. ADBI Communication Productions.

Halasz, F. and Moran, T.P. (1982). Analogy considered harmful. In *Proceedings of the Conference on Human Factors in Computing Systems* (Gaithersburg, Maryland 1982, pp. 383-386.

Hammersley, M. (Ed). (1993). *Social Research: Philosophy, Politics, Practice.* London: Sage.

Hampson, P.J., Marks, D.F., and Richardson, J.T.E. (1990). *Imagery: Current Developments.* London and New York: Routledge.

Hanson, N.R. (1965). *Patterns of Discovery: an enquiry into the conceptual foundations of science.* Cambridge: Cambridge University Press.

Haraway, D. (1976). *Chrystals, Fabrics and Fields: Metaphors of Organicism in Twentieth Century Developmental Biology.* New Haven and London: Yale University Press.

Harman, G. (1965). 'The Inference to the Best Explanation' *Philosophical Review* 74: 88-95.

Hartland, J. (1993). *The Machinery of Medicine: An analysis of algorithmic approaches to medical knowledge and practice.* University of Bath: Unpublished PhD thesis.

Haste, H. (1993). *The Sexual Metaphor.* Hertfordshire: Harvester Wheatsheaf.

Hatt, G.L. (1995). *Feeling Low: The Emergence of a Concept of Low Blood Pressure and the Representation of an Embodied Identity.* University of Bath: unpublished PhD thesis.

Head, H. (1920). *Studies in Neurology.* London: Froede, Hodder and Stoughton.

Hinsley, D.A., Hayes, J.R. and Simon, H.A. (1977). From words to equations: Meaning and representation in algebra and word problems. In Just, M.A. and Carpenter, P.A. (Eds). *Cognitive Processes in Comprehension.* Hillsdale, NJ: Erlbaum.

Hirschauer, S. (1991). 'The Manufacture of Bodies in Surgery'. *Social Studies of Science* Vol 21,pp. 279-319.

Hoffman, R; (1992). *Psychology of Expertise.* Berlin: Springer Verlag.

Holland, J.H., Holyoak, K.J., Nisbett, R.E. and Thagard, P.R. (1986). *Induction: Processes of Inference, Learning and Discovery.* Cambridge, MA: MIT Press.

Hopwood, N. (1999). 'Giving Body to Embryos: Modeling, Mechanism and the Microtome in Late Nineteenth-Century Anatomy' *Isis* 90: 462-496.

Hutchins, E. (1983). In Gentner, D. And Stevens, A. (eds). *Mental Models* 191-225. Hillsdale, NJ: Lawrence Erlbaum Associates.

Hutchins, E. (1990). The technology of team navigation. In Galegher, J, Kraut, R.E. and Edigo, C. (eds). *Intellectual teamwork: Social and technological foundations of cooperative work.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Johnson, M. (1987). *The Body in the Mind: The bodily basis of meaning, imagination and reason.* Chicago and London: University of Chicago Press.

Johnson, T.J. (1972). *Professions and Power.* London: Macmillan.

Johnson, T.J. (1984). Professionalism: Occupation or Ideology? In Goodlad, S. (Ed). *Education for the Professions: Quis Custodiet?* 17-25. SRHE and NFER-Nelson.

Johnson-Laird, P.N. and Wason, P.C. (1977). *Thinking: Readings in Cognitive Science.* Cambridge: Cambridge University Press.

Johnson-Laird, P.N. (1981). Mental models of meaning. In Joshi, A, Webber, B. And Sag, I. (eds). *Elements of discourse understanding* 106-126. Cambridge: Cambridge University Press.

Johnson-Laird, P.N. (1983). *Mental Models: Towards a Cognitive Science of Language, Inference and Consciousness.* Cambridge: Cambridge University Press.

Johnson-Laird, P.N. and Byrne, R. (1991). *Deduction.* Hove: Lawrence Erlbaum Associates.

Johnson-Laird, P.N. (1993). *Human and Machine Thinking.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Jolicoeur, P. and Kosslyn, S.M. (1985). Is time to scan visual images due to demand characteristics? *Memory and Cognition* 13, 320-332.

Josephson, J.R. and Josephson, S.G. (1996). *Abductive Inference: computation, philosophy, technology.* Cambridge: Cambridge University Press.

Katz, P. (1981). 'Ritual in the Operating Room'. *Ethnology* Vol 20, pp. 335-50.

Kaufmann, G. (1990).Imagery effects on problem solving. In Hampson, P.J., Marks, D.F. and Richardson, J.T.E. *Imagery: Current developments* 169-196. London and New York: Routledge.

Kearsey, J and Turner, S. (1999). How useful are the figures in school biology textbooks? *Journal of Biological Education.* 33 (2) 87-94.

Keller, S.B. (1998). 'Sections and Views: visual representation in eighteenth-century earthquake studies.' *British Journal for the History of Science.* 31: 129-59.

Kitney, R. (2000). 'Imaging, Visualisation and Virtual Reality in Medicine'. Paper given at *Visualisation in Surgery* symposium at Imperial College. Part of the BA Festival of Science. Saturday 9 September 2000.

Klahr, D. (Ed). (2000). *Exploring Science: The cognition and development of discovery processes.* Cambridge, MA, London, UK: MIT Press.

Knorr-Cetina, K. (1981). *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science.* Oxford: Pergamon.

Knorr-Cetina, K. (1983). 'The ethnographic study of scientific work: towards a constructivist interpretation of science'. In Knorr, K. and Mulkay, M. *Science Observed: Perspectives on the Social Study of Science* 115-140. London and Beverly Hills: Sage.

Kosslyn, S. M (1973). Scanning visual images: Some structural implications. *Perception and Psychophysics* 14, 90-94.

Kosslyn, S. M. (1980). *Image and Mind.* Cambridge, MA: MIT Press.

Kosslyn, S. M (1987). Seeing and imagining in the cerebral hemispheres: A computational approach. *Psychological Review* 94, 148-175.

Kosslyn, S. M. (1994). *Image and brain: the resolution of the imagery debate.* Cambridge MA: MIT Press.

Kosslyn, S.M. (1995). Mental Imagery. In Kosslyn, S.M. and Osherson, D.N. (eds) *Visual Cognition* 267-296. Cambridge, MA, London, UK: MIT Press.

Kosslyn, S.M and Jolicoeur, P. (1980). A theory-based approach to the study of individual differences in mental imagery. In Snow, R.E., Federico, P.A. and Montague, W.E., *Aptitude Learning and Instruction: Cognitive Process Analysis of Aptitude.* Vol 2, 139-175. NJ: Erlbaum Associates.

Kosslyn, S.M; Ball, T.M. and Reiser, B.J. (1978). Visual images preserve metric spatial information: Evidence from studies of image scanning. *Journal of Experimental Psychology: Human Perception and Performance* 4, 47-60.

Kosslyn, S.M; J. Brunn, K.R. Cave & R.W. Wallach (1984). 'Individual differences in mental imagery ability: A computational analysis'. *Cognition* 18, pp. 195-243.

Kosslyn, S.M., Holzman, J.D., Farah, M.J. and Gazzaniga, M.S. (1985). A computational analysis of mental image generation: Evidence from functional dissociations in split brain patients. *Journal of Experimental Psychology: General,* 114, 311-341.

Kosslyn, S.M., Segar, C., Pani, J.D. and Hillger, L.A. (1990). What is imagery for? *Journal of Mental Imagery* 14, 131-152.

Kosslyn, S.M., Alpert, N.M., Thompson, W.L., Maljkovic, V., Weise, S.B., Chabris, C.F., Hamilton, S.E., Rauch, S.L. and Buonanno, F.S. (1993). 'Visual mental imagery activates topographically organised / visual cortex: PET investigations'. *Journal of Cognitive Neuroscience* 5, 263-287.

Kosslyn, S.M. and Osherson D.N. (eds). (1995). *Visual Cognition.* Cambridge, MA and London UK: MIT Press.

Kress, G.R. and van Leeuwen, T. (1990). *Reading Images.* Victoria, Australia: Deakin University Press.\

Kuhn, T.S. (1962). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.

Lakoff, G. and Johnson, M. (1980). *Metaphors We Live By.* Chicago and London: University of Chicago Press.

Lane, D.R.and Cooper, B. (1994). *Veterinary Nursing* Vols.1 and 2. London: Pergamon.

Larkin, J.H. and Simon, H.A. (1987). Why a Diagram is Sometimes Worth Ten Thousand Words. *Cognitive Science* **11**: 65-100.

Latour, B. And Woolgar S. (1979). *Laboratory Life: The Social Construction of Scientific Facts.* London and Beverly Hills: Sage.

Latour, B. (1986). Visualization and Cognition: Thinking with Eyes and Hands. *Knowledge and Society: Studies in the Sociology of Culture Past and Present.* Vol. 6, pp. 1-40.

Latour, B. (1990). Drawing Things Together. In Lynch, M and Woolgar, S. (Eds.) *Representation in Scientific Practice* 19-68. London: MIT Press.

Lave, J. (1997). 'What's special about experiments as contexts for thinking?' In Cole, M. et al *Mind, Culture and Activity* 57-69. Cambridge: Cambridge University Press.

Leakey, R.E. and Lewin, R. (1992). *Origins Reconsidered: In Search of What Makes Us Human.* NY: Bantam Doubleday Publishing.

Lederman, S.J. and Klatzky, R. (1997). 'Relative availability of surface and object properties during early haptic processing'. *Journal of Experimental Psychology Human Perception and Performance* 23: 1680-1707

Lofland, J. (1971). *Analysing Social Settings.* Belmont, CA: Wadsworth.

Lynch, M. (1985). *Art and Artifact in Laboratory Science: A study of shop work and shop talk in a research laboratory.* London: Routledge and Kegan Paul.

Lynch, M and Woolgar, S. (1990). *Representation in Scientific Practice.* London: MIT Press.

MacAndrew, C. (1979). 'On the notion of drunkenness', in Pattison, E.M. et al (Eds), *Emerging Concepts of Alcohol Dependence. New York: Springer-Verlag.*

McCall, G. and Simmons, J. (1969). *Issues in Participant Observation.* NY: Addison-Wesley.

Mc Keithen, K.B., Reitman, J.S, Reuter, H.H. and Hirtle, S.C. (1981). Knowledge Organisation and Skill Differences in Computer Programmers. *Cognitive Psychology* 13: 307-325.

MacKenzie, D. And Spinardi, G; (1995). 'Tacit Knowledge, Weapons Design and the Uninvention of Nuclear Weapons'. *American Journal of Sociology* 101: 44-99.

Magee, B. (1985). *Popper.* London: Fontana Press.

Mazzolini, R. (1998). 'Felice Fontana and his Models of the Human Body'. Paper given at the Wellcome Symposium for the History of Medicine (with the Science Museum) *Models in the sciences, technology and medicine: displaying the third dimension.* Wellcome Institute and Science Museum, London, 13-14 November 1998.

Merleau-Ponty, M. (1962. *The Phenomenology of Perception.* Trans. Colin Smith. London: Routledge and Kegan Paul..

Michell, A.R. and Watkins, P.E. (1993). *An Introduction to Veterinary Anatomy and Physiology.* Cheltenham: BSAVA.

Miller, A.I. (1996). *Insights of Genius: Imagery and creativity in science and art.* N.Y: Springer-Verlag.

Millerson, G. (1964). *The Qualifying Associations.* London: Routledge.

Neisser, U. (1976). *Cognition and Reality.* San Francisco: Freeman.

Nersessian, N. (1992). How do Scientists Think? In Giere, R.N. (ed) *Minnesota Studies in the Philosophy of Science Vol. XV: Cognitive Models of Science* 3-44. Minneapolis: University of Minnesota Press.

Nersessian, N. And Greeno, J. (1990). Multiple Abstracted Representations in Problem Solving and Discovery in Physics. *Proceedings of the Cognitive Science Society* **11**: 77-84.

Newell, A. (1980). 'Physical Symbol Systems'. *Cognitive Science* **4**: 135-83.

Newell, A. (1982). 'The Knowledge Level' *Artificial Intelligence* 18: 82-106.

Newell, A. and Simon, H.A. (1972). *Human Problem Solving.* Englewood Cliffs, NJ: Prentice-Hall.

Newman, K. (1996). *Fetal Positions: Individualism, Science, Visuality.* Stanford University Press.

Nickles, T. (1988). 'Reconstructing Science: discovery and experiment'. In D. Balens and J.P van Bendegem (Eds) *Theory and Experiment* 33-53. Dordrecht and Boston: Reidel.

Norman, D.A. (1983). Some observations on mental models. In Gentner, D. And Stevens, A. (eds). *Mental Models* 1-19. Hillsdale, NJ: Lawrence Erlbaum Associates.

Norman, D.A. (1986). Cognitive engineering. In Norman, D.A. and Draper, S.W. (eds) *User centered system design* 31-62. Hillsdale, NJ: Lawrence Erlbaum Associates.

Norman, D.A. (1993). Cognition in the Head and in the World; An Introduction to the Special Issue on Situated Action. *Cognitive Science* **17,** 1-6.

Oakhill J. And Garnham, A. (Eds.) (1996). *Mental Models in Cognitive Science: essays in honour of Phil Johnson-Laird.* Hove: Psychology Press.

Ondaatje, M. (2000). Quoted in Jaggi, M. 'The Soul of a Migrant'. *The Guardian Weekend.* April 29 2000.

Orr, J. (1990). 'Sharing Knowledge, Celebrating Identity: Community Memory in a Service Culture' in Middleton, D., and D. Edwards *Collective Remembering* 169-89. Newberry Park, California: Sage.

Pack, C. (1975). 'Towards a phenomenology of transcription' in Garfinkel, H. (Ed.) *Studies of Work.* London: Routledge and Kegan Paul.

Paivio, A. (1971). *Imagery and Verbal Processes.* N.Y: Holt, Rinehart and Winston.

Paivio, A. (1991). *Images in Mind: The Evolution of a Theory.* London: Harvester Wheatsheaf.

Pasveer, B. (1993). Coding and Decoding: The Skill of Reading Medical X-Ray Photographs. *Medicine and Change: Historical and Sociological Studies of Medical Innovation.* Proceedings of the Symposium INSERM, held in Paris 21-23 April 1992. Ed. Ilana Lowy. Montrouge, France: Institut de la Recherche Medicale, 1993.

Persaud, T.V.N (1997). *A History of Anatomy: The Post-Vesalian Era.* Springfield, Illinois: Thomas.

Petherbridge, D. (1998). 'Translations: Representation and Dimensionality. The Discourse of the 2D and 3D in Obstretrical Representations'. Paper given at the Wellcome Symposium for the History of Medicine (with the Science Museum) *Models in the sciences, technology and medicine: displaying the third dimension.* Wellcome Institute and Science Museum, London, 13-14 November 1998.

Pinch, T., Collins, H.M. and Carbone, L; (1996). 'Inside Knowledge: second order measures of skill'. *Sociological Review* pp. 163- 184.

Pinch, T., Collins, H.M. and Carbone, L; (1997). 'Cutting Up Skills: Estimating Difficulty as an Element of Surgical and Other Abilities'. In S.R. Barley and J.E. Orr (Eds). *Between Craft and Science: Technical Work in US Settings* 101-112. Ithaca and London: Cornell University Press.

Pinker, S; (1997). *How the Mind Works.* London: Penguin Press.

Polanyi, M; (1958). *Personal Knowledge.* London and Henley: Routledge and Kegan Paul.

Popper, K.R. (1959). *The Logic of Scientific Discovery.* London: Hutchinson.

Popper, K. (with J.C. Eccles) (1977). *The Self and its Brain.* Springer International.

Pratt, P.W. (1992). *Laboratory Procedures for Veterinary Technicians.* California: American Veterinary Publications.

Pylyshyn, Z.W. (1973). 'What the mind's eye tells the mind's brain: A critique of mental imagery'. *Psychological Bulletin* 80, 1-24.

Pylyshyn, Z.W. (1978). 'Imagery and Artificial Intelligence'. In C.W. Savage (Ed). in *Perception and Cognition: Issues in the Foundations of Psychology* 19-55. Minnesota Studies in the Philosophy of Science Vol 9. Minneapolis: University of Minnesota Press.

Pylyshyn, Z.W. (1979a). The rate of 'mental rotation' of images: a test of a holistic analogue hypothesis. *Memory and Cognition* 2, 329-336.

Pylyshyn, Z.W. (1979b). Validating computational models: a critique of Anderson's indeterminacy of representation claim. *Psychological Review* 86, 383-394.

Pylyshyn, Z.W. (1981). The Imagery Debate: Analogue Media Versus Tacit Knowledge. *Psychological Review* Vol. 88 (1) 16-45.

Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction.* Amsterdam: Elsevier.

Rayner, A.D.M. *Degrees of Freedon: Living in Dynamic Boundaries.* London: Imperial College Press.

Reddy, M.J. (1979). The conduit metaphor: A case of frame conflict in our language about language. In Ortony, A. (ed). *Metaphor and Thought* 284-324. Cambridge: Cambridge University Press.

Regoczei, S. (1992). Comments on chapters in this volume. In Hoffman, R. *Psychology of Expertise.* Berlin: Springer Verlag.

Regoczei, S. And Hirst, G. (1992). 'Knowledge and Knowledge Acquisition in the Computational Context'. In Hoffman, R. (ed) *Psychology of Expertise.* Berlin: Springer Verlag.

Richardson, J.T.E. (1980). *Mental Imagery and Human Memory.* London: Macmillan.

Roberts, K.B. and Tomlinson, J.D.W. (1992). *The Fabric of the Body: European Traditions of Anatomical Illustration.* Oxford: Clarendon Press.

Robinson, J.A. (1965). A machine-oriented logic based on the resolution principle. *Journal of Association for Computing Machinery,* **12:** 23-41.

Rooke, G. (1994). *Making Space for Visual Representations.* University of Bath: unpublished MSc dissertation.

Rosch, E. (1977). Classification of real world objects: Origins and representations in cognition. In Johnson-Laird, P.N. and Wason, P.C. *Thinking: Readings in Cognitive Science* 212-222. Cambridge: Cambridge University Press.

Roschelle, J. And Greeno, J. (1987). *Mental Models in Expert Physics Reasoning.* Technical Report No. GK-2. University of California, Berkeley.

Rudwick, M. J.S. (1976). 'The Emergence of a Visual Language for Geological Science 1760-1840. *History of Science* X1V: pp.149-195.

Rumelhart, D.E. (1975). Notes on a schema for stories. In Bobrow, D.G. and Collins, A (eds). *Representation and Understanding: Studies in Cognitive Science* 211-236. New York: Academic Press.

Rumelhart, D.E. (1980). Schemata: the building blocks of cognition. In Spiro, R. et al (eds) *Theoretical Issues in Reading Comprehension* 33-58. Hillsdale, NJ: Lawrence Erlbaum.

Rumelhart, D.E. and Norman, D.A. (1981). Analogical processes in learning. In Anderson, J.R. (ed) *Cognitive Skills and their Acquisition* 335-359. Hillsdale, NJ: Erlbaum.

Ryle, G. (1949). *The Concept of Mind.* San Francisco: Hutchinson.

Saxe, G.B. (1997). 'Selling Candy: A Study of Cognition in Context.' In Cole, M. et al *Mind, Culture and Activity,* 330-337. Cambridge: Cambridge University Press.

Schaffer, S; (1997). Experimenter's Techniques, Dyer's Hands and the Electric Planetarium. *Isis* 88, 456-483.

Schank, R.C. (1975). *Conceptual Information Processing.* Amsterdam: North-Holland Publishing Co.

Schank, R.C. and Abelson, R.P. (1977). *Scripts, plans, goals and understanding.* Hillsdale, NJ: Lawrence Erlbaum.

Schumacher, R.M. and Czerwinski, M.P. (1992). Mental Models and the Acquisition of Expert Knowledge. In Hoffman, R; (1993). *Psychology of Expertise.* Berlin: Springer Verlag.

Schunn, C.D. and Klahr, D. (2000). 'Multiple-space search in a more complex discovery micro-world' In Klahr, D. (Ed). *Exploring Science: The cognition and development of discovery processes.* Cambridge, MA, London, UK: MIT Press.

Scribner, S. (1997). 'Mind in action: a functional approach to thinking.' In Cole, M. et al *Mind, Culture and Activity,* 354-368. Cambridge: Cambridge University Press.

Selzer, R. (1981). *Mortal Lessons: Notes on the Art of Surgery.* London: Chatto and Windus.

Shaw, C. and McKay, H. (1969). *Juvenile Delinquency and Urban Areas.* Chicago: Chicago University Press.

Shelley, C. (1996). 'Visual Abductive Reasoning in Archaeology' *Philosophy of Science* 63, pp. 278-301.

Shepard, R.N. (1975). Form, formation and transformation of internal representations. In *Information Processing and Cognition: The Loyola Symposium,* ed. R.L. Solso. Hillsdale, NJ: Erlbaum Associates

Shepard, R.N. (1978). The mental image. *American Psychologist* 33, 125-137.

Shepard, R. and Cooper, L. (1982). *Mental Images and their Transformations.* Cambridge, MA: MIT Press.

Shepard, R.N. and Feng, C. (1972). A chronometric study of mental paper folding. *Cognitive Psychology* 3, 228-243.

Shepard, R.N. and Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science* 171, 701-703.

Sirois, M. (1995). *Veterinary Clinical Laboratory Procedures.* NY and London: Mosby.

Sloboda, J; (1986). ' What is Skill?' In Gellately, A; (ed) (1986). *The Skilful Mind,* 1-16 . Milton Keynes: Open University Press.

Sontag, S. (1991). *AIDS and its Metaphors.* London: Penguin.

Stafford, B.M. (1991). *Body Criticism.* Cambridge, Mass; London UK: MIT Press.

Stafford, B.M. (1992). 'Depth Studies: Illustrated Anatomies from Vesalius to Vicq d'Azyr'. *Caduceus* 1992: 8 (2) 39-47.

Stella, F. (1986). *Working Space.* Cambridge: Cambridge University Press.

Suchman L; (1987). *Plans and Situated Actions: The Problem of Human / Machine Communication.* Cambridge: Cambridge University Press.

Taffinder, N. (2000). 'Hands on virtual reality simulation' Demonstration given at the *Visualisation in Surgery* symposium at Imperial College, 9 September 2000. Part of the BA Festival of Science.

Thagard, P. (1999). *How Scientists Explain Disease.* Princeton, NJ: Princeton University Press.

Tippett, L. (1992). 'The generation of mental images: A review of neuropsychological research and theory. *Psychological Bulletin* 112, pp. 415-432.

Todd-Pokropek, A.E. (1998). 'The Cutting Edge of Virtual Reality: medical image analysis.' *The Times Higher* December 4, 1998, p.33.

Trabasso, T., Rollins, H. and Shaughnessy, E. (1971). Storage and verification stages in processing concepts. *Cognitive Psychology* **2**: 239-89.

Tufte, E.R. (1990). *Envisioning Information.* Cheshire, Connecticut: Graphics Press.

Turner, B.S. (1990) The anatomy lesson: a note on the Merton thesis. *The Sociological Review* Vol 38 (1990), 1-18.

Vasseleu, C. 1991). Life Itself. In Diprose, R. and Ferrell, R. *Cartographies: Post Structuralism and the Mapping of Bodies and Spaces* 55-64. Sydney: Allen and Unwin.

Vygotsky, L.S. (1960). The development of higher mental functions. [Quoted in J.V. Wertsch (1985) *Vygotsky and the social formation of mind.* Cambridge, MA: Harvard University Press].

Vygotsky, L.S. (1978). *Mind in Society.* Cambridge, MA: Harvard University Press.

Wason, P.C. (1959). The processing of positive and negative information. *Quarterly Journal of Experimental Psychology* **11**: 92-107.

Wason, P.C. (1965). The contexts of plausible denial. *Journal of Verbal Learning and Verbal Behaviour* **4**; 7-11.

Wason, P.C. and Johnson-Laird, P.N. (1972). *Psychology of Reasoning: structure and content.* London: Batsford.

Weinstein, D. (1975). *Drivers' Work.* Unpublished thesis. University of California.

Welford, A.T; (1958). 'On the Nature of Skill' in Legge, D. (1970) (ed). *Skills.* Harmondsworth: Penguin Books.

Wertsch, J.V. (1985) *Vygotsky and the social formation of mind.* Cambridge, MA: Harvard University Press.

West, G. (Ed). (1995). *Blacks Veterinary Dictionary* (18 th Ed.). London: A. & C. Black.

Wilson, R. (1954). 'Teamwork in the Operating Room.' *Human Organisation* Vol 12, 9-14.

Whyte, W. (1955). *Street Corner Society.* Chicago: University of Chicago Press.

Winch, P. (1958). *The Idea of a Social Science and its Relation to Philosophy.* London: Routledge and Kegan Paul.

Wittgenstein (1922/1966). *Tractatus Logico-Philosophicus.* London: Routledge and Kegan Paul.

Wittgenstein (1953). *Philosophical Investigations* Oxford: Blackwell.

Woodgate, D.A. (1998). *From Novice to Expert in Veterinary Nursing: snapshots in professional skill development.* Unpublished thesis submitted for the degree of Masters in Social Research. University of Bath.

Wundt (1916). *Elements of Folk Psychology.* London: Allen and Unwin.